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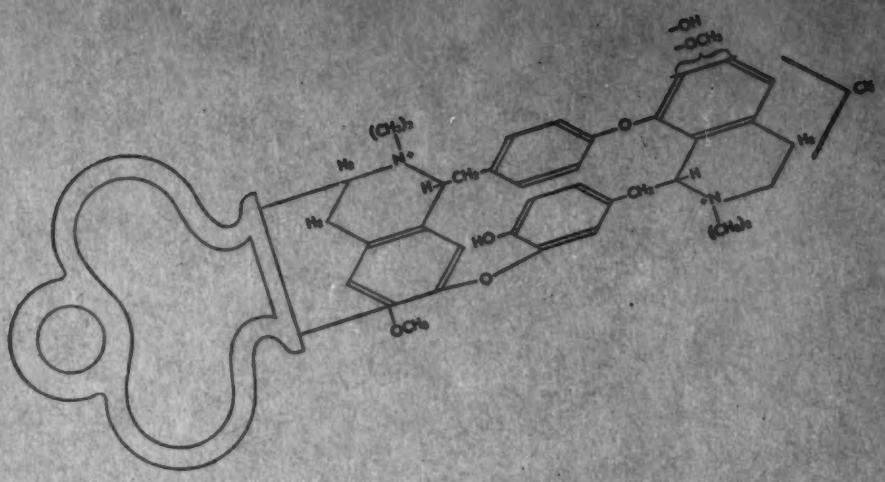

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VOLUME 84 JUNE, 1947 NUMBER 6

# THE COMBINED THORACICOABDOMINAL APPROACH WITH PARTICULAR REFERENCE TO ITS EMPLOYMENT IN SPLENECTOMY

B. NOLAND CARTER, M.D., Cincinnati, Ohio

WHEN one reviews the literature dealing with splenectomy performed for an *enlarged* spleen and reflects on his own experiences in such operations, it becomes evident that the technical difficulties encountered are chiefly those resulting from lack of completely adequate exposure. Various types of incisions have been advocated for splenectomy, all aimed at providing an easier and freer access to the operative field. Among these are the "T" incision with one arm placed through the left rectus muscle and the other extending through the muscles of the abdominal wall toward the flank, the subcostal incision placed just below and parallel to the costal margin, and the transverse incision beginning at the midline half way between the xiphoid and umbilicus and extending through the abdominal wall laterally to just above the crest of the ilium. In the case of a grossly enlarged spleen none of these incisions is adequate because they do not allow access to those portions of the operative field in which lie the most potent sources of danger and difficulty. These areas are the upper pole of the spleen, its diaphragmatic surface, and its posterior aspect. At these points are found the dense adhesions, the dilated thin-walled collateral vessels, and some of the normal splenic ligaments. Until these structures are divided the spleen cannot be mobilized sufficiently to permit easy and safe management of the pedicle. It is, however, in attempts at blind mobilization of the large spleen that inaccessible vessels are torn and nearby structures damaged. In an attempt to meet this situation, Singleton has advised the opening of the lesser peritoneal sac and ligation of the splenic vessels as they course along the upper surface of the pancreas as a first step in the procedure, and, having thus controlled the main blood supply to the spleen, to proceed with its mobilization and removal.

When a large spleen is encountered its very size in comparison with the length of the abdominal incision which can be made over it is a potent factor militating against easy exposure. The spleen is so large that it fills the incision of its own accord, thus making easy access to remote portions of the operative field practically impossible. This is particularly true where there is a narrow costal angle with a rib cage covering the greater part of the upper left quadrant. Actually the enlarged spleen lies mostly beneath the ribs in contact with the diaphragm (Fig. 1), placing the surgeon at a distinct disadvantage when working through an abdominal incision.

Since 1939 it has been our practice to perform esophagogastrostomies through a transthoracic approach with division of the dia-

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phragm, and it has become increasingly evident to us that such an approach offers unusually good exposure of the spleen. Consequently, this type of approach was recently utilized in this clinic for the removal of a spleen of normal size which had been ruptured for several days before admission of patient to hospital and which was surrounded by a fibrosing blood clot. In this instance the costal arch was extremely narrow and the diaphragm quite high, so that it was considered simpler to approach the spleen through the chest. The thorax was opened by an incision placed in the seventh interspace, and the ribs were spread widely; the diaphragm was opened, and the spleen lying in clear view could be easily freed from its many adhesions and the pedicle brought into the operative field. The simplicity of this procedure immediately suggested the possibility of attacking an enlarged spleen by a transthoracic approach. It was felt, however, that when the spleen was grossly enlarged the incision through the diaphragm might not be adequate to permit easy delivery of the enlarged organ and that one would be handicapped in much the same way as he would be if he were using an abdominal incision. Therefore it seemed logical to utilize a combined abdominal and thoracic incision, the thoracic portion of which would give a direct approach to those aspects of the spleen inadequately exposed by an abdominal incision, while the abdominal portion would permit wide access to the lower portion of the spleen and also permit the thoracic cage to be spread more widely. The over-all length of the combined incision would allow for easy delivery of the enlarged spleen.

The opportunity to utilize this proposed incision first presented itself in June, 1946 in the case of a 37 year old white man with Banti's syndrome. On June 6, 1945 he had been admitted to the Cincinnati General Hospital with a perforated duodenal ulcer for which he was operated upon with a simple closure of the ulcer. His convalescence was a stormy one complicated by a right subphrenic abscess and a right empyema. During this admission to the hospital he showed a slight degree of icterus with some ascites. Under bed rest and digitalis these manifestations rapidly disappeared. At the time of jaundice and ascites the laboratory findings were as follows: cephalin flocculation test 2½+ in 24 hours and 3+ in 48 hours; bromsulfalein retention 65 per cent in 30 minutes and 100 per cent in 5 minutes; blood phosphatase 5.9 hippuric acid excretion test 175 grams; galactose tolerance test 3.5 grams excreted.

His second admission was on September 12, 1945. The spleen was enlarged at this time, being three fingerbreadths below the costal margin, and had apparently been the site of an infarct causing pain in the upper left quadrant and tenderness over spleen. A diagnosis of probable Banti's disease was made and he was referred to the out-patient clinic. During the next 6 months he had repeated splenic infarcts and the previously noted enlargement of the spleen continued, but there was no ascites.

He was admitted to the surgical service in the Cincinnati General Hospital on June 17, 1946 complaining of weakness, jaundice, and dull aching pain in the left upper quadrant. He showed evidence of considerable loss of weight and appeared chronically ill. There was a slight icterus present not accompanied by itching. The liver could not be felt. The spleen was grossly enlarged, with its lower pole 2 inches below the level of the umbilicus, and was very firm. There was no ascites. The laboratory findings were as follows: cephalin flocculation test 3+ in 24 hours and 3+ in 48 hours; prothrombin time 12 seconds (12 to 13 seconds normal); bromsulfalein test showed 100 per cent in 5, 30, and 45 minutes; blood urea nitrogen 14 milligrams per cent; Kahn negative; icteric index 7. X-ray studies revealed varices scattered throughout lower half of esophagus. After suitable replacement therapy patient was operated upon June 20, 1946.

The operative technique employed was as follows: Under intratracheal gas oxygen and ether anesthesia a transverse incision was made from a point midway between the xiphoid and the umbilicus to the costal margin at the site of the eighth costal cartilage and prolonged in the eighth interspace to the midscapular line (Fig. 2, insert). The rectus and oblique muscles were divided in line with the skin incision down to the peritoneum and the muscles on the chest wall were incised down to

the pleura (Fig. 2). The peritoneum was now opened as far as the costal cartilage which was cut across, and the pleura opened throughout the length of the thoracic portion of the wound. Both the abdomen and the thorax having been thus entered, the diaphragm was incised from its attachment at the costal margin to the posterior angle of the thoracic incision (Fig. 3). A rib spreader was inserted and a remarkably wide exposure of the greatly enlarged spleen resulted. Actually one could *see* the organ from its superior to its inferior poles (Fig. 4). The diaphragmatic surface could be visualized completely as well as the entire greater curvature of the stomach. Many dense and vascular adhesions could be seen extending from the spleen to the diaphragm at the upper pole and on the posterior lateral surface of the spleen. The splenic flexure of the colon was in plain view and the left kidney could be made out readily. The splenocolic and splenorenal ligaments were ligated and divided (Fig. 5). The vascular adhesions mentioned were ligated and divided with great ease since they were completely in the operative field and under direct vision. The gastrosplenic ligament was like-

Fig. 1. The position of the enlarged spleen beneath the rib cage, necessitating blind dissection in order to mobilize it for delivery through the abdominal incision.

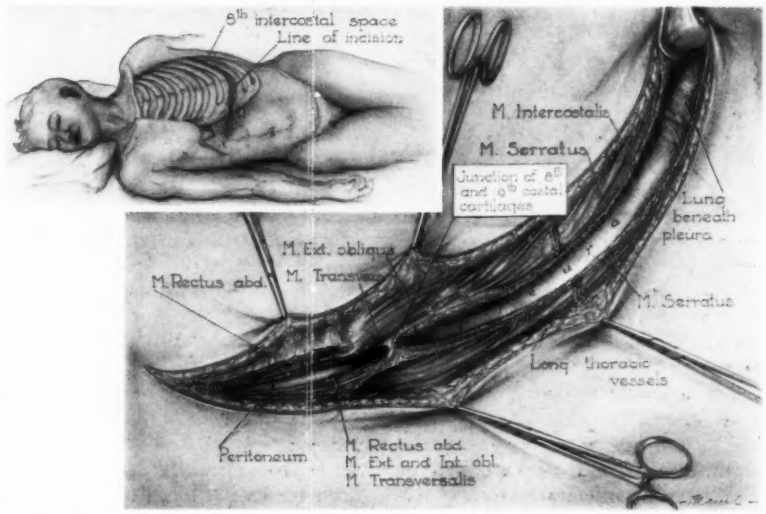


Fig. 2. The incision has been made in the line shown in the insert, and has been deepened through the muscles down to the pleura and peritoneum. The 8th costal cartilage has not been divided.

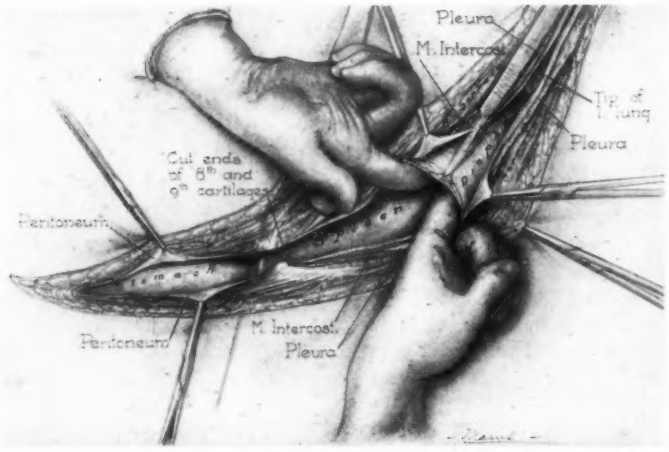


Fig. 3. The peritoneum has been opened, the costal cartilage divided, and the pleural cavity entered. The diaphragm is now being divided, thus throwing the peritoneal and pleural cavities into one.

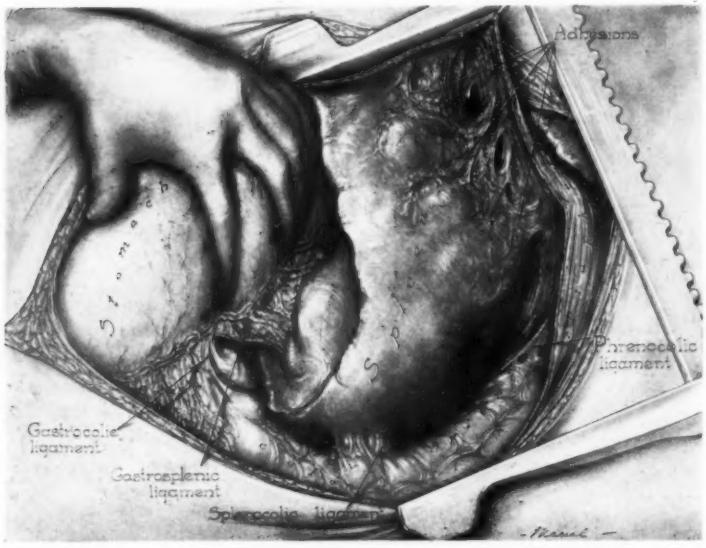


Fig. 4. The extent of the exposure obtained in the case of a grossly enlarged and adherent spleen. Note the free access obtained to the diaphragmatic surface of the spleen with its many vascular adhesions.

wise ligated in segments and divided without difficulty (Fig. 6). The spleen was then delivered readily through the long widely spread incision and turned toward the right (Fig. 7). The tail of the pancreas was visualized and the splenic pedicle freed from it. With the left hand beneath the spleen and its pedicle the latter was readily isolated into its artery and veins (Fig. 8). The artery was doubly ligated and divided and the spleen removed. There

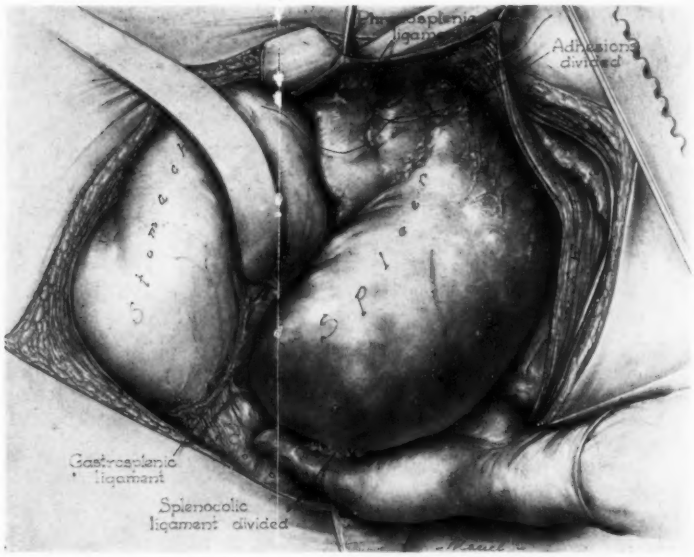


Fig. 5. The splenocolic and splenorenal ligaments have been divided. The vascular adhesions between the spleen and the undersurface of the diaphragm are being ligated prior to division.

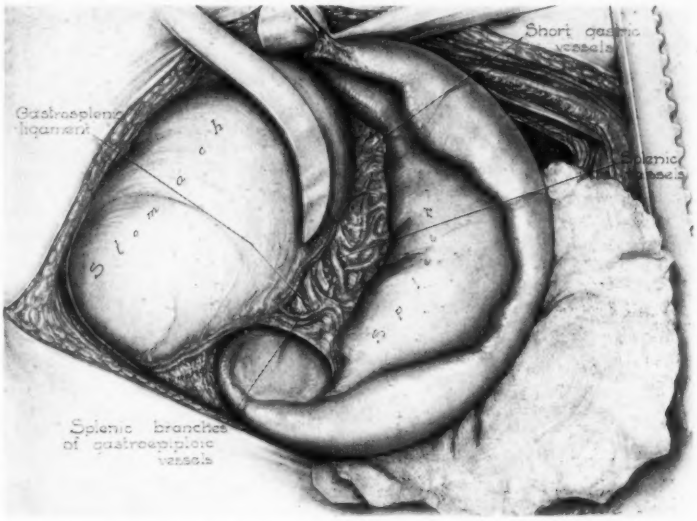


Fig. 6. The exposure of the gastrosplenic ligament, showing the ease with which the ligament can be isolated into segments and divided. The splenic vessels are likewise shown.

was virtually no loss of blood since all structures could be visualized before ligation and division. It was never necessary to perform blind dissection in an inaccessible re-

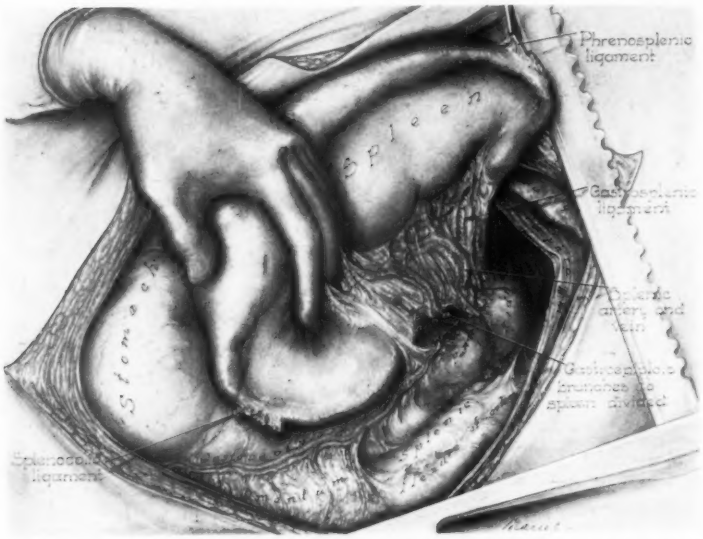


Fig. 7. The spleen having been mobilized is turned to the right and freed from the tail of the pancreas.

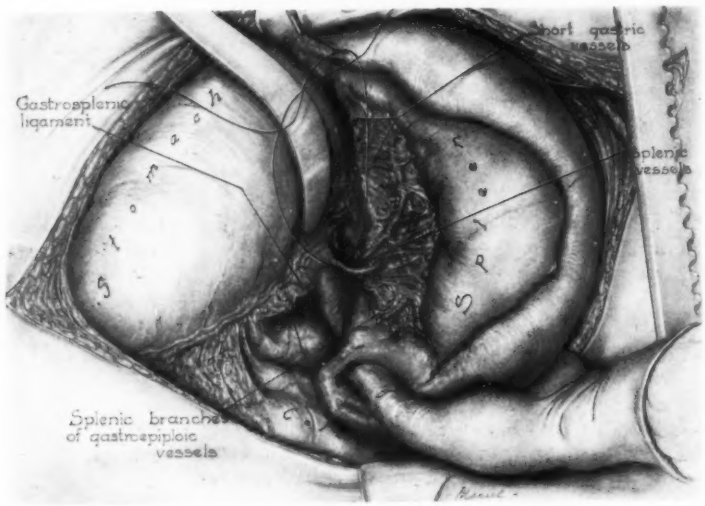


Fig. 8. Exposure of the pedicle. The arteries have been ligated and divided. A vein is being ligated.

gion, the entire procedure was done with great ease.

The diaphragm was sutured with interrupted figure-of-eight sutures of silk (Fig. 9A); the chest wall was closed by means of one pericostal suture of braided silk and a continuous suture of silk in the overlying muscles (Fig. 9B). Two sutures of silk were placed in the perichondrium of the divided cartilage and gave a snug approximation of this structure.

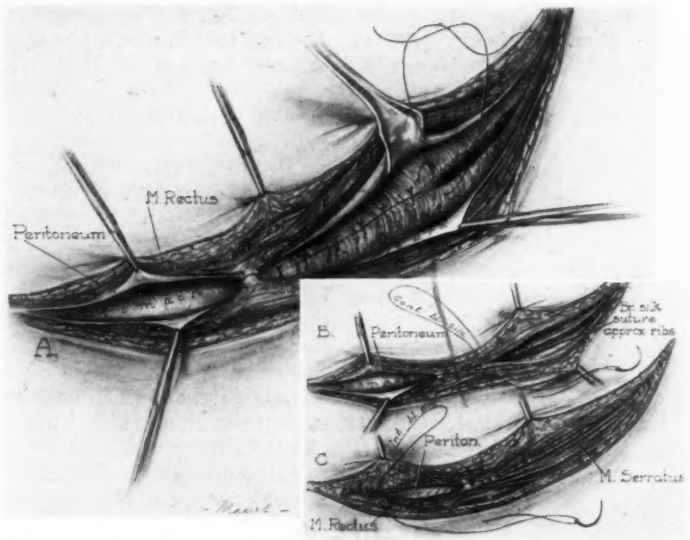


Fig. 9. A, The diaphragm is being closed with figure-of-eight sutures. B, One pericostal suture of braided silk has been tied and has approximated the ribs. The muscles of the chest wall are being closed with a continuous silk suture. C, The chest wall closure has been completed. The peritoneum has been closed with a continuous suture of silk and the sheath of the rectus muscle is being sutured with figure-of-eight stitches of silk.

The peritoneum was sutured with continuous silk and the sheaths of the divided abdominal muscles were closed with interrupted figure-of-eight sutures of silk (Fig. 9C). The skin was sutured with interrupted silk. No drainage of the pleural cavity or wound was instituted. The operation was well tolerated and at no time did the pulse go above 80. The blood pressure was 140/85 at start of the operation and 102/80 at end of procedure.

The convalescence was uneventful. The patient was singularly free from pain after operation and was ambulatory on the second postoperative day. The wound healed by first intention and 7 months after operation there was no evidence of postoperative hernia.

After this rewarding experience with the incision described it was decided that considerable advantages were afforded which would make it applicable to operations for other surgical conditions encountered in the left upper quadrant of the abdomen. It was next employed in the removal of a leiomyoma situated adjacent to the esophagus on the anterolateral aspect of the stomach. Again the access to the lesion was strikingly easy and the tumor was resected without the difficult, vigorous, and often futile attempts at retraction of the costal margin, and the assumption of awkward positions by the surgeon. It has been utilized also in the resection of the cardiac portion of the stomach for carcinoma, and in removal of lesions of the lower end of the esophagus followed by esophagogastrostomy.

## HISTORICAL REVIEW

In an effort to determine the experiences of others in the use of this approach which we had never seen utilized nor recalled having seen reported, the literature was surveyed and was found sufficiently interesting to warrant a short historical review. The history of the combined thoracicoabdominal approach dates back to the last decade of the nineteenth century, and the efforts of Lannelongue and Micheli to gain a wider exposure for operations on the cardiac portion of the stomach. Von Mikulicz, as reported by Gottstein, per-

formed the first operation leading to this approach to be done on a living patient in 1896. His procedure, however, was specifically designed to avoid damage to the pleura. After making an incision from the xiphoid to the umbilicus, then perpendicularly to the left, and then perpendicularly upwards, he resected the ribs and carefully laid back the pleura before extirpating a carcinoma of the lower esophagus and cardia. He modified the incision somewhat at a later operation (1899), so that after the initial midline incision, the second started perpendicularly and then shifted to go obliquely upwards and out; but he again retained the integrity of the pleura. Both patients died shortly after operation.

Marwedel recorded the next such attempt in 1903. After intensive study on the cadaver, he successfully performed an operation for stenosis of the esophagus, using an incision which followed the costal arch. He also avoided entering the pleura, and devised a complicated maneuver for securing wide exposure without entering that cavity.

In 1909, Tiegel (16, 17) reported a case of Henle, in which a thoracicoabdominal approach was carried out in two stages. Laparotomy was performed first, operability determined, and the upper part of the stomach mobilized and incised below the tumor. A Murphy button was placed in the distal opening, and the upper part closed by suture. After closure of the abdominal wound, a left thoracotomy was performed, and the esophagus severed above the tumor. An esophagogastrostomy was then completed with the button. The patient died shortly after operation of collapse of the left lung.

Wendel performed a similar operation in 1909; however, he performed thoracotomy first, opening the pleura under pressure. A tumor was found on the posterior wall of the esophagus, partly above and partly below the diaphragm. Laparotomy was done after closure of the thoracic wound, and tumor resected through abdomen. This patient also died shortly after operation; autopsy a bloody effusion in the left pleural cavity.

In 1910, Janeway and Green carried out a two stage procedure, performing laparotomy first, followed by thoracotomy. Their patient died 54 hours after operation of empyema. At that time, in reporting the case, they made the recommendation that in the future the operation should be performed through one incision rather than two, suggesting the incision actually used by Ohsawa 23 years later.

Ohsawa (1933) was the first to report a combined incision, with 8 survivals in 18 operations for tumors of the lower esophagus and cardia. He made a midline or a left pararectal incision from the seventh costal cartilage to just above the umbilicus, and after opening the peritoneum to inspect the viscera, continued this incision upward and laterally along the chest wall to the inferior angle of the scapula (Fig. 10A). After resecting segments of the seventh and eighth ribs, he incised the pleura in the seventh intercostal space. The costal arch in the seventh interspace was cut through, and the diaphragm divided to the esophageal hiatus, thus converting the abdominal and thoracic cavities into a single operative field.

This operation did not meet with immediate approval, but rather was felt to be one of too great magnitude. In condemning the procedures of both Marwedel and Ohsawa, Garlock (4, 5) suggested exploration through a small upper left rectus incision for determination of operability. After closure of this wound, he preferred to operate through the thorax.

Loucks and Wu reported 6 successful resections of carcinoma of the esophagus via the thoracicoabdominal approach in 1942. They began the incision in the lower part of the interscapular region, and continued downward and anteriorly along the seventh rib, extending into the hypochondrium to the lateral border of the left rectus muscle (Fig. 10C). After resecting the entire length of the seventh rib, they entered the pleura and divided the costal margin through the cartilage. With the peritoneal cavity exposed at lower end of the incision, a single operative field was made of pleural cavity and upper abdomen.

Brock (1942) made a midline supraumbilical incision, with a second obliquely upwards along the sixth intercostal space from the middle of the first (Fig. 10B). After dividing the costal margin, and separating the diaphragm from the costal attachment, the operative

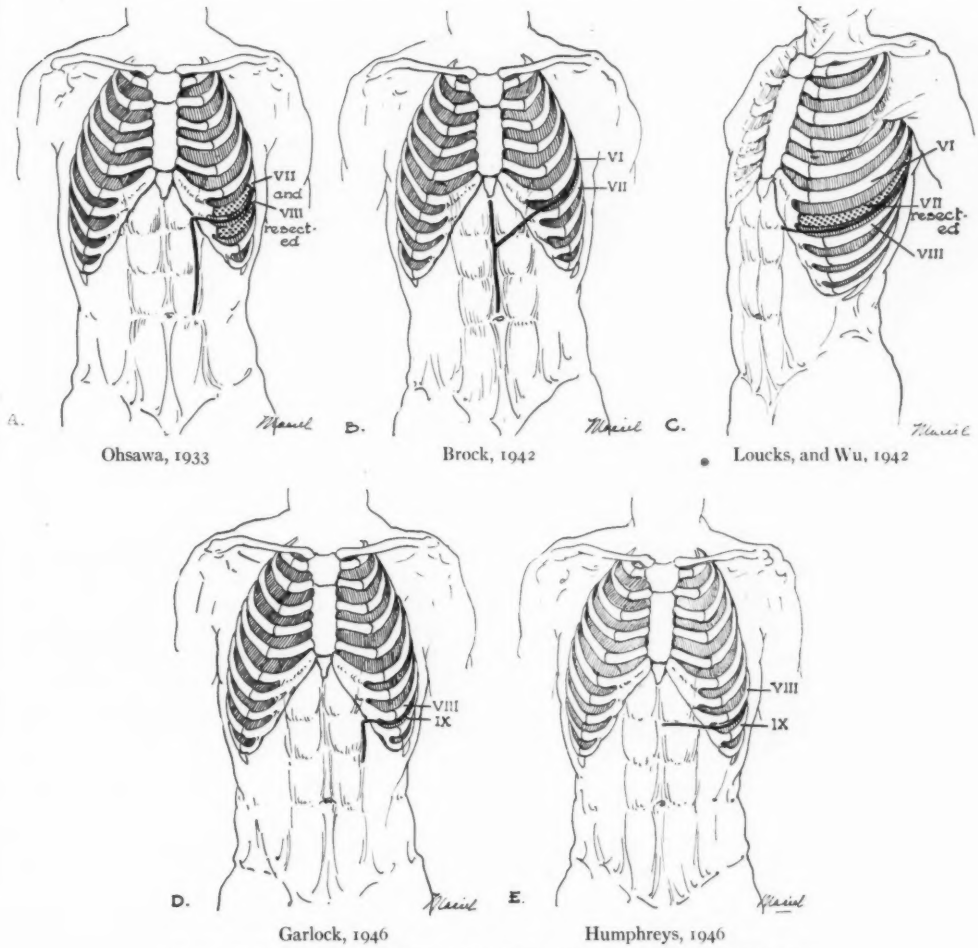


Fig. 10. Types of combined thoracicoabdominal incisions with authors and dates.

field for tumor of the cardia was obtained. The importance of abdominal exploration prior to opening of the chest was stressed.

In 1946 Humphreys reported 12 operations using the combined incision for carcinoma involving both the esophagus and the cardia, with a 50 per cent mortality. He opened the abdomen through an oblique incision from the costal margin at the level of the eighth interspace to a point just right of the midline, about 2 centimeters above the umbilicus. After determination of operability, this incision was extended directly upward into the chest over the eighth interspace to the posterior axillary line (Fig. 10E). The diaphragm was divided from its origin at the costal margin between the eighth and ninth ribs as far as the esophageal hiatus. The esophagus was freed upward as far as necessary, and the stomach freed toward the pylorus, also as far as was necessary. Of the 6 patients surviving the operation, 3 died of metastases, and 3 were alive at the time of the report, 5, 6, and 15 months after operation respectively. Five

combined incision procedures were carried out for carcinoma involving the cardia only, with no operative mortality. Two of these operations were carried out entirely through the abdomen, and in the other 3, the thoracic esophagus was not disturbed. Two of these patients were living at the time of the report, 2 and 2½ years after operation respectively.

The most recent report of the thoracicoabdominal approach is that of Garlock (6) (1946). His procedure, adopted after discussion with Humphreys, began with a 5 inch incision along the outer edge of the rectus muscle. After completion of the abdominal exploration, the first incision was extended over to, and along the line of, the eighth interspace (Fig. 10D). The intercostal muscles and pleura were divided, and the diaphragm cut across as far as the esophageal hiatus. This procedure produced a wound which could be opened as widely as necessary by a rib-spreader.

## COMMENTS

There are several distinct advantages in the use of the combined thoracicoabdominal incision. The chief one of these is that it affords a wide and ready access to portions of the abdomen, not obtainable when abdominal or thoracic approaches alone were utilized. Unless one has actually used or seen the operative procedure it is difficult to realize the ease with which operations can be performed on organs situated high in the upper quadrants of the abdomen. We have not used it on the right side but it should be extremely useful in an attack on certain lesions of the right lobe of the liver. The performance of the abdominal portion of the incision first permits exploration to determine operability after which the thoracic incision may be added if indicated.

Though the operative approach appears to be one of considerable magnitude and is more time-consuming both in its performance and in its closure, in our experience it is as well tolerated, under intratracheal positive pressure anesthesia, as are extensive abdominal incisions. The ease of access afforded with consequent more rapid performance of operative procedures compensates for the additional time required to make and to close the incision. The patients on whom this combined incision has been used have been remarkably comfortable after operation and certainly have not had more pain than those with large abdominal incisions. The intercostal incision without rib resection has been adequate in the way of exposure though there is no good reason why a rib should not be resected or why short segments of the ribs bordering the incision should not be removed if additional exposure is needed. None of our patients has shown instability of the chest wall after division of the eighth costal cartilage, which is quite small at its point of division and which can be well approximated by sutures in the perichondrium after the pericostal suture has been tied. No postoperative hernias have been observed, though the longest time since operation has been only 8 months.

## CONCLUSIONS

1. The combined thoracicoabdominal approach described has been well tolerated under intratracheal anesthesia with positive pressure.

2. A remarkably good exposure is afforded which permits easy surgical attack on lesions high in the upper quadrants of the abdomen.

3. The postoperative course of the patients thus operated upon has been striking in lack of pain or discomfort, and no postoperative hernias have occurred although the follow-up period has been only a few months.

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# REOPERATIVE SURGERY FOR RECURRENT PEPTIC ULCERATIONS

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THIS report is based on 73 subtotal gastrectomies in 71 patients whose previous gastric operations proved unsuccessful.

Five patients have had their first operation by myself. Three of these 5 original operations were subtotal gastrectomies with Finsterer's exclusion operation in which the antral mucosa was left intact. These patients developed jejunal ulcers and were operated on again by me. The fourth patient had a Billroth I resection for a gastric ulcer. She developed symptoms because of severe adhesions. The Billroth I operation was dismantled and turned into a typical retrocolic Hofmeister-Finsterer procedure. In the fifth patient a perforated duodenal ulcer was excised and a Judd pyloroplasty performed. The patient underwent a resection later because of the recurrences of the duodenal ulcer. Of the 66 patients with gastrectomies who had had their original operations elsewhere, 2 were operated upon by me several times subsequent to their first operations elsewhere.

The 71 gastrectomized patients had had 107 gastric operations of various types previous to the final gastrectomy.

Epigastric pain, particularly shifting to the left, following a gastrectomy frequently denotes a jejunal ulcer. Hemorrhage or pain in a patient who has had any type of a Billroth II gastrectomy suggests a jejunal ulcer or jejunitis. The symptomatology of recurrent and jejunal ulceration is not necessarily characterized by the pain and food relief syndrome. X-ray and gastroscopic examination and even abdominal exploration often fail to give positive evidence of the presence of a frank jejunal ulcer unless the gastrojejunal anastomosis is dismantled during the exploration.

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Epigastric pain, nausea, and vomiting may also be caused by motor disturbances from severe adhesions or a faulty technique.

A brief analysis (Tables I and II) is also made of 300 personally performed primary gastrectomies for benign gastroduodenal ulcerations.

TABLE I.—ANTECEDENT GASTRIC PROCEDURES IN 71 PATIENTS

| | |
|---|---|
| No. of patients | 71 |
| No. of previous gastric operations | 107 |
| Total No. of gastric operations | 178 |
| No. of personally performed secondary radical gastrectomies | 73 |
| No. of patients originally operated upon elsewhere | 66 |
| No. of patients originally operated upon by me | 5 |

TABLE II.—TYPE OF ANTECEDENT GASTRIC PROCEDURES WHICH RESULTED IN FAILURE

| | No. Cases |
|---|---|
| Gastroenterostomy with enteroanastomosis | 1 |
| Gastroenterostomy (retrocolic) | 30 |
| Von Eiselsberg exclusion operation with gastroenterostomy | 4 |
| Finsterer's original exclusion operation (mucosa not ablated) with radical gastrectomy | 6 |
| Finsterer's original exclusion operation (mucosa not ablated) with a minimal resection | 1 |
| Finsterer's original exclusion operation (mucosa not ablated) with radical gastrectomy and enteroanastomosis | 1 |
| Dismantling of gastroenterostomy | 1 |
| Conservative retrocolic gastrectomy | 1 |
| Billroth I gastrectomy | 1 |
| Duodenojejunostomy | 1 |
| Excision of duodenal diverticulum | 1 |
| Excision of gastric ulcer | 6 |
| Excision of chronic and perforated duodenal ulcers and various pyloroplastic procedures | 36 |
| Miscellaneous and undetermined procedures, such as gastrotomy, closure of perforation with pyloroplasty, exploration, and postoperative obstruction | 11 |
| Jejunostomy | 1 |
| Closure of perforated jejunal ulcer | 7 |
| Radical retrocolic gastrectomy | 0 |

## THE ETIOLOGY AND PREVENTION OF POSTOPERATIVE JEJUNAL ULCERS

Postoperative jejunal ulcers take place after a gastroenterostomy and also following a Billroth II gastrectomy. Only a few primary jejunal ulcers have been reported. It is evident

then that it is the new environment at the jejunal segment following the gastrojejunal anastomosis which is responsible for the jejunal ulcerations. Exalto, Mann and Williamson, Ivy, and Dragstedt, Steinberg, and Proffitt, as well as numerous other investigators have succeeded in producing jejunal ulcers with regularity by diverting the alkaline duodenal contents away from a newly created gastrojejunal anastomosis. Though the efforts of these numerous investigators have been important, the surgeons preceded the experimental workers by unwittingly performing operations on patients which were similar to the experimental methods of Exalto and others. The gastroenterostomy, the "Y" anastomosis of Roux, the enteroanastomosis and the Von Eiselsberg exclusion operation were frequently followed by jejunal ulcerations. Such postoperative ulcerations are more significant than the ulcers produced by the various experiments. Under parallel conditions of research, animal experimentation cannot hope to compete with the importance of careful investigations carried out on patients. The short-circuiting operations of Exalto are mutilating in the manifest physiological changes which they produce (18). In order to mitigate the mutilating short-circuiting operations of Exalto and also of Mann and Williamson, I have sidetracked the alkaline duodenal contents 60 centimeters or less from the pylorus in all the animal experiments previously reported. The introduction of histamine beeswax by Code and Varco for the production of experimental ulcers has now replaced all the unphysiological short-circuiting operations. The grave nutritional and metabolic disturbances which are brought about by animal experiments do not follow the usual surgical procedures used in the treatment of peptic ulcerations.

It becomes apparent that the failures after gastric operations are more important than the animal experiments when it comes to evaluating the conditions under which postoperative ulcers develop. Statistics reporting jejunal ulcerations are of no value unless careful and detailed descriptions of the operative procedures are given. In reporting the disappointments and failures following gastrectomy, it is not a matter of indifference simply to group the resections into Billroth I or Billroth II. From the experimental evidence and from clinical experience certain modifications of the Billroth II procedures are destined to result in a great many more failures than the standard subtotal retrocolic gastric resection popularized by Finsterer. It is quite obvious that if minimal resections, subtotal retrocolic resections, or antecolic resections and also exclusion operations or resections combined with the "Y" anastomosis or enteroanastomosis are all placed in one group, the percentage of failures will be credited to the gastrectomy irrespective of the method used. It is also my impression that the original Billroth II procedure which creates a blind terminal sac will compare unfavorably with the typical Hofmeister-Finsterer method in spite of a radical resection.

The analysis of the failures after gastric operations parallels the lessons learned from the experimental laboratory. Using the modified Exalto short-circuiting operation I was able to demonstrate in a large series of experimental animals that only a subtotal resection is able to protect the animal against jejunal ulcerations. However, if the gastrojejunal stoma is very small, a jejunal ulcer will take place in spite of a major resection. Some few years ago, while visiting a gastroenterologist, a patient was presented who had had repeated stomach resections and who still harbored a jejunal ulcer in spite of the fact that only a very small part of the stomach was left. The gastroenterologist was at a loss not only as to the prognosis but also as to the cause of this tragic condition. It was suggested that a Murphy button anastomosis which would result in a very small stoma could well have explained the repeated jejunal ulcerations. The surgical record actually showed a Murphy button had been used in the gastrojejunal anastomosis. Kinks and narrowing of the lumen of the jejunum distal to the gastrojejunal anastomosis should also be avoided. A kink distal to the jejunal anastomosis may produce a stasis in the jejunum and create a favorable condition for the development of a jejunal ulcer (18).

Again, it is not a matter of indifference whether one removes a smaller or a larger par

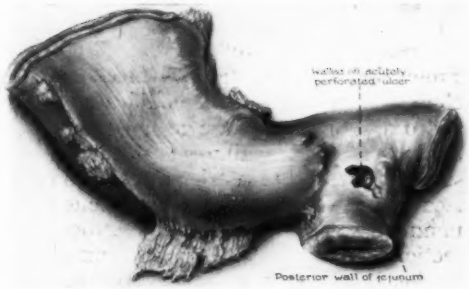


Fig. 1. No. B-37555-E. H. About three-fourths of the remaining gastric tissue was removed following a previous gastrectomy for a duodenal ulcer. An acutely perforated jejunal ulcer took place within 1 year following the original gastrectomy which was presumed to have been radical.

of the stomach. It has been suggested that it is not necessary to resect three-fourths or four-fifths of the stomach tissue since a certain percentage of jejunal ulcerations will take place irrespective of the amount of stomach resected. There is more than slender evidence to refute this assertion. It has already been mentioned that animals cannot be uniformly protected against jejunal ulcers by minimal resections (18). "It was conclusively demonstrated that a subtotal resection of the stomach with a wide stoma performed according to the Billroth II method (Finsterer-Hofmeister) has never been followed by a peptic ulcer in our experiments, even in the presence of an artificial kink in the jejunum. This we consider of scientific and clinical interest and importance. On the other hand the Billroth I anastomosis end-to-end and the minimal resection of the stomach according to the Billroth II method have given rise to jejunal ulcers" (18). Lorenz and Schur, pioneers in gastric resection, have reported that the reduction in acidity after gastrectomy parallels the amount of gastric tissue removed. Jejunal ulcerations were not infrequent following minimal resections. Some surgeons of experience have abandoned the retrocolic type of resection because of postoperative difficulties or because of possible injury to the middle colic artery if reoperation should become necessary for a jejunal ulcer. Although the antecolic anastomosis is easier to perform and is less time-consuming, it is my opinion that the frequency of jejunal ulcerations following the

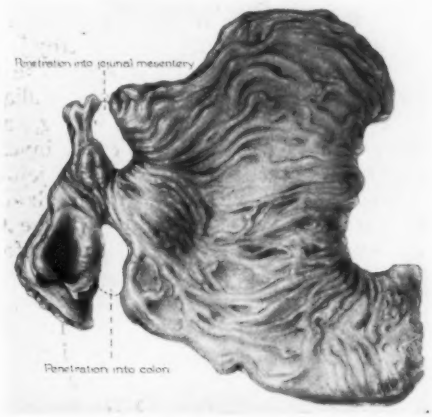


Fig. 2. No. B-64270-E. H. About three-fourths of the remaining gastric tissue including a jejunal segment was removed following a previous gastrectomy for a duodenal ulcer. Jejunal ulcerations with repeated hemorrhages took place within 1 year following the first gastrectomy which was presumed to have been radical.

antecolic minimal resection will either approximate or exceed the frequency of jejunal ulcerations following the posterior gastroenterostomy. In a series of 260 consecutive antecolic conservative gastrectomies, Rienhoff reports 83 cases, or 32 per cent, of patients who developed such complications as pain, hemorrhage, or jejunal ulcers. Pain or hemorrhage which follows a gastrectomy most frequently denotes jejunal ulcer or jejunitis. Kiefer reports 6.9 per cent jejunal ulcers and 4.6 per cent hemorrhage in 173 patients who have undergone extensive gastric resections for duodenal ulcer. The percentage of the proved and presumed jejunal ulcers is not as high as in the Rienhoff report because of the more radical type of the resections in the Lahey technique. The 11.5 per cent of unsatisfactory results, however, is high in comparison to the subtotal, standard retrocolic resection. The discrepancy between the results in the subtotal retrocolic resection and the results in the Lahey subtotal antecolic resection is in all probability due to the long proximal jejunal loop which is a predisposing factor to jejunal ulcerations (9). Rienhoff and Kiefer's reports are of significance since the technique of gastrectomy in both instances has been described in detail.

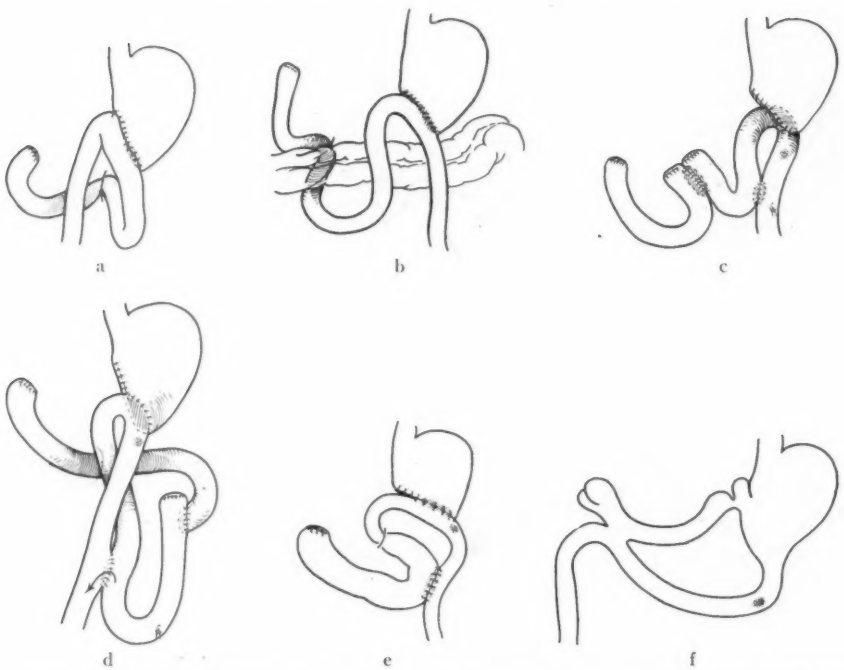


Fig. 3. An analysis of operative procedures which have been used for the cure of jejunal ulcers. a, In spite of its correct anatomical relationship, the antecolic resection with a long proximal jejunal loop attached to the greater curvature wall will have a tendency to dump the gastric contents into the proximal jejunal loop. Such an anatomical relationship may cause dyspeptic symptoms and vomiting from the sudden emptying of a dilated proximal jejunal loop into the lumen of the gastric remnant. Many surgeons of experience attach the proximal jejunal loop to the greater curvature because such arrangement allows for no rotation of the jejunum on its axis as in the Hofmeister-Finsterer technique where the proximal jejunal loop is attached to the lesser curvature angle. b, An antecolic anastomosis with more than one-half of the gastric tissue remaining will not prove as successful in preventing jejunal ulcerations as a retrocolic subtotal resection. c, A gastric resection with an enteroanastomosis. An enteroanastomosis placed close to the gastrojejunal opening may not have the evil effects of the total diversion of the alkaline duodenal contents. In order to insure against further jejunal ulcerations, no type of enteroanastomosis is recommended distal to the gastrojejunal anastomosis. d, A gastric resection with a long jejunal loop anastomosis and also an enteroanastomosis will create favorable conditions for recurrent jejunal ulcerations. e, A duodenojejunal anastomosis will have a tendency to divert the alkaline duodenal contents from the gastrojejunal stoma and, therefore, create favorable conditions for a new jejunal ulcer. f, Another type of a duodenojejunostomy which will also have a tendency to divert the alkaline duodenal contents away from the gastrojejunal anastomosis. This type of reconstructive surgery does not satisfy the physiological concepts for a successful gastrectomy.

Before I had the opportunity to witness the technique of gastrectomy performed by two European surgeons of high reputation, I was puzzled at their published results which were not as favorable as those reported by Finsterer. One of the two above mentioned surgeons used the original typical retrocolic Billroth II method which produced a blind terminal sac; the other surgeon used a long loop, antecolic anastomosis. Neither of these surgeons, however, reported his particular technique. My own disappointing results with the original Finsterer exclusion operation and with the proximal "Y" anastomosis are of more importance than carefully controlled animal experimentations. Of the 14 patients who had undergone exclusion operation with a radical gastrectomy performed by me 3 returned with jejunal ulcers. Proximal "Y" anastomoses, in which the gastrojejunal anastomosis was usually placed about as far from the ligament of Treitz as in the antecolic method, were performed in

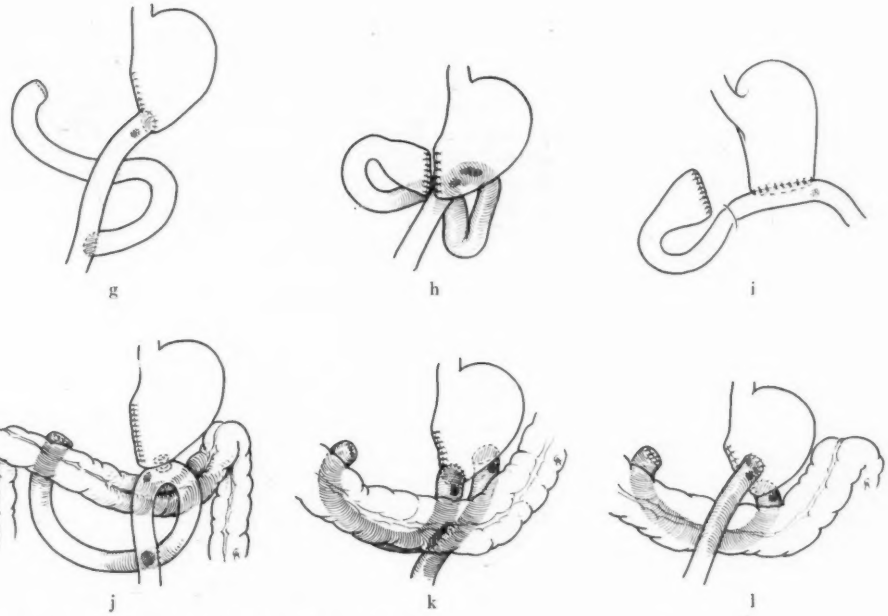

Fig. 3. g, This represents the typical and original distal "Y" anastomosis of Roux. It is most likely to result in a recurrent jejunal ulcer. h, This represents a type of exclusion operation recommended by Von Eiselsberg and Devine. The proximal gastric segment is closed at its distal extremity creating a pouch. This type of an operation will rarely escape a jejunal ulcer. i, This is another type of the Von Eiselsberg or the Devine procedure. A jejunal ulcer is also most likely to take place following this procedure. j, A long loop antecolic anastomosis is a predisposing factor to jejunal ulcerations. An enteroanastomosis diverts the alkaline duodenal secretions away from the gastrojejunal anastomosis. A Murphy button anastomosis creates a small gastrojejunal stoma which will produce a jejunal ulcer in spite of a radical resection. The original Billroth II method with the closure of the cut end of the stomach produces a blind pouch which also creates favorable conditions for a jejunal ulcer. k, There are 5 errors in this operation, any one of which would be sufficient to create favorable conditions for a renewed jejunal ulcer: (1) the gastric remnant is too large; (2) the closure of the distal end of the stomach creates a blind sac; (3) the end-to-side anastomosis creates a small stoma; (4) The enteroanastomosis diverts the alkaline contents from the gastrojejunal anastomosis; (5) the Schmilinsky procedure is most likely to result in a jejunal ulcer and also dyspeptic symptoms from the regurgitation of the duodenal contents into the stomach. l, This is another Schmilinsky procedure which is most likely to bring recurrence of a jejunal ulcer and also to result in severe dyspeptic symptoms from the regurgitation of bile and pancreatic juice into the stomach. m, The author's proximal "Y" anastomosis with a temporary jejunostomy. Nine such reconstructive procedures resulted in 2 jejunal ulcers. Even if the proximal "Y" anastomosis allows the alkaline duodenal contents to bathe the gastrojejunal anastomosis, its construction requires a longer proximal jejunal loop than in the standard retrocolic method. The proximal "Y" anastomosis is more complicated than the other methods of reconstruction.

9 patients, 2 of whom returned with jejunal ulcers. Of the 339 personally performed short afferent loop radical retrocolic gastrectomies not 1 patient returned with a jejunal ulcer. Wangensteen reported 350 short afferent loop subtotal gastrectomies. Of these only 1 patient developed a jejunal ulcer (Figs. 1 and 2).

### OPERATIVE PROCEDURES USED FOR THE CURE OF JEJUNAL ULCERS AND LIKELY TO RESULT IN FAILURE

1. All types of short-circuiting operations which divert the alkaline duodenal contents away from the gastrojejunal anastomosis. The outstanding examples of such operations are the original "Y" anastomosis of Roux and the enteroanastomosis of Braun, particularly if the latter is placed some distance from the gastrojejunal anastomosis.

2. Minimal gastrectomy.

3. The Schmilinsky operation.

4. The various types of the exclusion operation in spite of a radical gastrectomy unless the gastric mucosa is completely ablated. However, it is not always possible to know whether the gastric mucosa is completely removed in the Wilmanns modification of the Finsterer exclusion procedure in the presence of induration and edema. A part of the pyloric mucosa may be inverted into the duodenal lumen and it may later regenerate along the muscular walls of the pyloric remnant. This actually happened in 1 of our patients who developed a fistula following this type of exclusion operation. No jejunal ulcer resulted in this instance. In another exclusion procedure with much cartilaginous induration, there is reason to believe that not all of the pyloric mucosa was removed. The patient was later operated upon elsewhere presumably for a jejunal ulcer. My modified pyloroplastic closure of the duodenum enables one to remove all of the pyloric mucosa.

5. Gastrectomy with a gastrojejunal anastomosis placed antecolic some distance from the duodenojejunal angle, particularly if the resection is minimal.

6. My proximal "Y" anastomosis.

7. A small gastrojejunal stoma (Murphy "button" operation) in spite of a major resection.

8. Kinks resulting in jejunal stenosis and stasis proximal or distal to the gastrojejunal anastomosis.

9. The original Billroth II anastomosis which may result in a blind sac distal to the gastrojejunal stoma.

10. Other operations which are likely to prove ineffectual for the cure of jejunal ulcers: (a) dismantling of the gastroenterostomy, (b) excision of the jejunal ulcer; (c) pyloroplasty; (d) a new gastroenterostomy; and (e) gastroduodenostomy.

### ANALYSIS OF POSTOPERATIVE DEATHS

There were 4 postoperative deaths in 300 primary gastrectomies and 3 deaths in 73 secondary gastrectomies. The combined operative mortality in 373 primary and secondary gastrectomies was 1.8 per cent. After reporting 117 primary gastrectomies in 1940 with a mortality of 2.6 per cent, there followed another group of 163 primary consecutive gastrectomies with 1 death (mortality 0.6). This death occurred in a patient operated on for acute massive hemorrhage from a duodenal ulcer. This analysis of mortality statistics represents no selected group of cases and includes all of the gastrectomies performed for peptic ulcers since 1924. Not a single gastroenterostomy was performed after 1926.

### CASE REPORTS OF PATIENTS WHO SUCCUMBED FOLLOWING A PRIMARY GASTRECTOMY

CASE 42. X, male, between 40 and 50 years old, was operated upon in a small private hospital for a large bleeding ulcer on the posterior wall of the duodenum which had perforated into the pancreas. The patient expired on the fifth day following the gastrectomy. No blood was available for transfusion in the hospital. This death could be considered as avoidable.

CASE 43. No. 8349, male, 69 years old, had a primary gastrectomy for a bleeding gastric ulcer. Patient died 2 weeks after the operation from a coronary infarction. This death was unavoidable.

CASE 44. No. A-8156, male, 36 years old, had a primary gastrectomy for an acutely bleeding ulcer. He had 7 blood transfusions previous to operation. Death was due to an overlooked perforation of a posterior duodenal ulcer caused by a finger which was introduced into the pylorus during the exploration. It is dangerous to force the finger through a stenosed duodenum since it may penetrate the posterior wall without being recognized. This death is to be considered as avoidable.

CASE 45. No. B-60712, female, 60 years old, had a primary gastrectomy for an acutely bleeding ulcer. This death was due to a fulminating enteritis. It is possible that a timely and generous use of plasma and blood might have prevented this fatality.

### FATALITIES FOLLOWING SECONDARY GASTRECTOMIES

CASE 46. No. B-54227, male, 58 years old, had a secondary gastrectomy following an operation for a

perforated ulcer and a gastroenterostomy. Death was due to massive atelectasis, edema, and fluid in the pleural cavity. Contributing cause in this case was the injudicious use of saline. Death in this case was preventable.

CASE 47. No. 65060, male, 38 years old, had a gastrectomy for a jejunal ulcer which followed a gastroenterostomy. Death was due to perforation of the transverse suture line in the jejunum and to the injudicious use of too much saline and fluids. Death was preventable.

CASE 48. No. 3846, male, 48 years old, had a gastrectomy for gastric and duodenal ulcer following 3 operations including a gastroenterostomy. Death was due to shock and gangrene of jejunal loop. Death was preventable.

TABLE III.—REOPERATION FOR JEJUNAL ULCERS FOLLOWING 373 PERSONALLY PERFORMED GASTRECTOMIES (371 PATIENTS)

| | No. of gastrectomies | Jejunal ulcers | Per cent jejunal ulcers |
|---|---|---|---|
| Primary and secondary gastrectomies with ulcer either removed or left *in situ* by various methods of exclusion* No. patients who survived | 339 | 0 | 0 |
| Primary and secondary subtotal gastrectomies combined with original Finsterer exclusion operation† No. patients who survived | 14 | 3 | 21.7 |
| Subtotal gastrectomies with the proximal "Y" anastomosis‡ No. patients who survived | 9 | 2 | 22.2 |

*The gastric mucosa was ablated in the distal remaining gastric segment.
†Gastric mucosa was not ablated in remaining distal gastric segment.
‡The proximal jejunal loop was long.

Though a jejunal ulcer may make its appearance many years following any type of gastrojejunal anastomosis, thus far not 1 of the 339 patients with primary and secondary standard short proximal loop retrocolic gastrectomies came to me for reoperation because of a jujunal ulcer. I have learned that 1 of the 339 patients who has had an exclusion operation with the mucosa ablated was reoperated upon elsewhere. It is possible that in this patient a remnant of gastric mucosa has regenerated along the denuded pyloric muscle. Another patient has advised us that he has left to consult a clinic because of epigastric pain and distress.

TABLE IV.—REVIEW OF 373 PRIMARY AND SECONDARY GASTRECTOMIES (371 PATIENTS)

| | No. | Mortality | Per cent |
|---|---|---|---|
| Primary gastrectomies including operations for acute massive hemorrhage | 300 | 4 | 1.3 |
| Secondary gastrectomies | 73 | 3 | 4.1 |
| Primary and secondary gastrectomies which includes every gastrectomy since 1924 | 373 | 7 | 1.8 |

All 4 deaths in the group of the primary gastrectomies occurred in patients who were admitted to the hospital for acute massive hemorrhages. All 4 patients were operated upon several days after admission. Only 2 of the 4 patients came to the operating room with the hemorrhage arrested. One of the 2 died 14 days after the operation from a coronary infarction. The other died from an overlooked perforated duodenal ulcer on the posterior wall. If the 2 fatalities which occurred in those patients who were exsanguinated and who came late for the operation with the hemorrhage unarrested were subtracted, the corrected mortality would be reduced to 0.8 per cent, or 2 deaths in 298 primary gastrectomies.

TABLE V.—END-RESULTS IN 71 PATIENTS WITH SECONDARY GASTRECTOMIES

| (Period of observation from 1 to 20 years) | No. |
|---|---|
| Patients having had multiple operations | 71 |
| Previous gastric operations in 71 patients | 107 |
| All gastric operations in 71 patients | 178 |
| Died from the operation in hospital | 3 |
| Died later: | |
| Cancer of the stomach | 1 |
| Cancer of the prostate | 1 |
| Jejunocolic fistula following exclusion operation with mucosa not ablated | 1 |
| Not returned for observation | 6 |
| Returned for observation | 59 |
| Perforated jejunal ulcer following the proximal "Y" anastomosis (long proximal anastomotic loop) | 1 |
| Hemorrhage following the proximal "Y" Anastomosis (long proximal anastomotic loop) | 1 |
| Satisfactory results (no pain or hemorrhage) | 57 |

## SUMMARY AND CONCLUSIONS

Seventy-one patients with 107 antecedent gastric operations have been subjected to 73 gastrectomies. The most common antecedent gastric operations were: gastroenterostomies, pyloroplasties, excision of ulcers, and the various types of atypical gastric resections. Thus far no patient has been operated on for a jejunal ulcer following a radical standard retrocolic resection. Altogether these 71 patients have had 178 gastric operations. Five of the 71 patients with recurrent ulcers were originally operated upon by myself.

An additional 300 patients were subjected to a primary gastrectomy because of a duodenal or gastric ulcer. The 371 patients who have been subjected to a gastrectomy because of a duodenal, jejunal, or gastric ulcer have had 95 previous gastric operations of various types performed elsewhere.

*Mortality.* The mortality in 71 patients with secondary gastrectomies was 4.1 per cent; in 300 primary gastrectomies, 1.3 per cent; and in 373 primary and secondary gastrectomies, 1.8 per cent. This does not represent a selected group of patients since it includes all the gastrectomies performed for any type of

simple or complicated case since 1924. The last gastroenterostomy was performed in 1926.

Since at least 5 of the 7 deaths were avoidable, the risk of the gastrectomy operation cannot be considered as contingent upon some insurmountable or unpredictable condition, but rather on the lack of supreme diligence in the technical execution of the operation or in the preoperative and postoperative care. No patient succumbed to the operation because of the many hours spent on the operating table. With the advent of contemporary supportive treatment during the anesthesia the additional time which the patient spends in the operating room should no longer disturb a considered planning and a considered execution of the operation.

*Morbidity.* There was not a single serious postoperative hemorrhage. The contents in the drainage bottle are frequently blood-stained in the first 24 hours. The double ligation of most of the mesenteric blood vessels and the introduction of hemostatic sutures along the gastrojejunal anastomosis prevents any serious postoperative bleeding.

There were 2 patients with postoperative gastric retention who were operated on. There is reason to believe that these 2 patients would have recovered without additional surgery. There were 2 other patients with gastric retention who recovered without further surgery.

*Postgastrectomy symptoms and disabilities.* Following the gastrectomy operation, the greatest majority of the patients display no serious or disabling symptoms. Such complaints as intolerance to certain foods, the feeling of fullness, perspiration, and rapid pulse following the ingestion of a meal, disappear or become less annoying at various periods after the operation. Fatigue, irritability, and nervousness are not as common as the postprandial symptoms, but these may persist for a longer period. Most of these symptoms also vanish in time. The failure to gain weight is most persistent in a good number of these patients. The postgastrectomy syndrome, though at times annoying in a few patients, has thus far incapacitated only 1 because of frequent spells of syncope. Thus far no patient has been hospitalized because of the postgastrectomy syndrome.

*The exclusion operation.* The exclusion operation of Finsterer in which the pyloric mucosa was removed according to the method of Wilmanns resulted in sinus or fistula formation in 7 instances. Of the 14 personally performed radical gastrectomies for duodenal ulcer in which the original Finsterer exclusion operation was employed and the mucosa was not removed, 3 patients developed jejunal ulcers. Of the 10 patients with gastrectomies who were originally operated upon elsewhere and who were later reoperated upon by me because of jejunal ulcers, in 8 the original operation represented some type of the exclusion procedure in which the pyloric mucosa was not removed. Even the Wilmanns type of the Finsterer exclusion operation in which the gastric mucosa is removed cannot always be considered as the ideal procedure. In the presence of edema and induration it is not always possible to determine whether all of the gastric mucosa is removed. A remnant of the gastric mucosa may regenerate along the denuded gastric musculature and bring about the same condition for the development of a jejunal ulcer as after the original exclusion operation. The modification of my original pyloroplastic closure of the duodenum prevents such complications.

It first seemed incredible to indict a small fragment of the remaining pyloric mucosa as the sole cause of jejunal ulcerations. The frequency of jejunal ulcers which follow all sorts of exclusion operations (Von Eiselsberg, Devine, and Finsterer methods), condemns this procedure and unless it is combined with a major retrocolic short proximal loop gastrectomy. It is not necessary to remove the duodenal ulcer but it is important to be certain that no gastric mucosa is left in the excluded part of the musculature.

*Proximal "Y" anastomosis with temporary* jejunostomy. There have been 11 patients who were subjected to secondary gastrectomies by this method. One patient died, another was found to have a gastric carcinoma. Of the 9 remaining patients with jejunal ulcerations who were subjected to the proximal "Y" anastomosis with a temporary jejunostomy, 1 patient had had a gastric hemorrhage about 2 years following the operation and an-

other was operated upon for a perforated jejunal ulcer. In spite of the fact that this type of a "Y" anastomosis allows the alkaline duodenal secretions to bathe the gastrojejunal anastomosis, it places the anastomosis some distance from the duodenojejunal angle. It, therefore, creates the same potential danger for a new jejunal ulcer as does the antecolic anastomosis. The proximal "Y" anastomosis with a temporary jejunostomy is also more difficult and time-consuming. It may, however, find an occasional indication.

*Results of radical gastric resection in patients with recurrent peptic ulcerations who were subjected to 107 antecedent gastric procedures of various types which resulted in failure.* Three patients died in the hospital; 2 died later from carcinoma; 1 died from a jejunocolic fistula following the Finsterer exclusion operation in which the gastric mucosa was not ablated. Two patients developed jejunal ulcers following my reconstructive gastrectomy with a proximal "Y" anastomosis. Six patients did not return for the follow-up study. Fifty-seven patients who have been operated upon for recurrent peptic ulcers and who were observed from 1 to 20 years, have, thus far, remained free from any symptoms such as epigastric pain or hemorrhage suggestive of jejunal ulcerations.

*Prevention of jejunal ulcer.* Of the 339 patients upon whom I performed primary and secondary radical gastrectomies of the standard retrocolic type and who were observed from 1 to 24 years, not 1 has returned for reoperation because of a jejunal ulcer. The jejunal ulcers were found following the gastroenterostomy, the exclusion operation, the minimal gastrectomy, the antecolic radical gastrectomy, the short-circuiting operations, such as the enteroanastomosis, the gastrectomy with a small stoma, and also the proximal "Y" anastomosis gastrectomy. The standard radical proximal short loop, retrocolic terminolateral gastrectomy with a sufficiently wide stoma, gives maximum protection against the dreaded jejunal ulcer. The ulcer diathesis has not been found to be a factor in the recurring jejunal ulcer. Every jejunal ulcer and its recurrence were found to follow the inadequate type of operation.

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# INFECTIONS OF THE COSTAL CARTILAGES AND STERNUM

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INFECTIONS of the costal cartilages and sternum present special problems in surgical treatment. Although the advent of chemotherapy has lessened the frequency and severity of suppuration of the chest wall, costal chondritis and sternal osteomyelitis still not infrequently require operative intervention. If the special problems concerned with the surgical management of infections of the costal cartilages and sternum are not properly understood, the results are often unsatisfactory and complete healing fails to occur. The present communication is concerned, therefore, with an analysis of the subject on the basis of personal experience and a review of the literature. A few illustrative cases are presented in detail.

## INFECTION OF THE COSTAL CARTILAGES

The special problems associated with infection of the costal cartilages are due to certain characteristics of hyaline cartilage as well as to the anatomic arrangement of these cartilages forming the anterior thoracic wall. Hyaline cartilage does not contain any blood vessels or nerves and derives its nutrition from the lymph. Because of its avascularity, this tissue is very vulnerable to infection. When denuded of its perichondrium and left exposed in an infected wound, cartilage acts much like a foreign body. When only a portion of a cartilage is resected, the cut surface of the remaining segment is not covered by perichondrium. Similarly, removal of only one of two or more fused cartilages will leave an area denuded of perichondrium at the site of fusion. Whenever a piece of cartilage, any part of which is denuded of perichondrium, projects into an infected wound, a persistent sinus may occur. Only if infection is minimal or the exposed part of the cartilage is covered with viable tissue before the necrosis begins, can sinus formation be avoided. In clean wounds, however, partial resection of cartilages may be done.

The upper seven ribs are connected to the sternum by costal cartilages which are a direct bridge between the anterior end of the bony rib and the sternum. The perichondrium encasing the cartilages is continuous with the periosteum of the rib. Fusion between any of the upper five cartilages is rare. The sixth and seventh cartilages sometimes articulate with each other lateral to the sternum. The eighth, ninth, and tenth cartilages do not reach as far as the sternum, but end in the lower margin of the preceding cartilage. The seventh to the tenth costal cartilages inclusive constitute the costal arch. It is usually possible, therefore, to remove one of the upper five cartilages without denuding the adjacent cartilage of its perichondrium. Exposed cartilage would project into the wound, however, if only one of the seventh, eighth, ninth, or tenth cartilages were removed, since each of these, and sometimes the sixth, has an area of fusion with the adjacent cartilage.

Chondritis due to pyogenic organisms may occur as a result of wounds, as a direct extension from an adjacent infection, following operation for drainage of suppurative foci and as a result of systemic infection. The staphylococcus and streptococcus are the most frequent pyogenic organisms found in costal chondritis. In past years, however, the typhoid and paratyphoid organisms were not infrequent causes of chondritis. Tuberculous involvement of the cartilages is still common, but the process is usually secondary to tuberculosis of adjacent structures, especially the pleura and the mediastinal lymph nodes. Various fungi, particularly actinomyces and blastomyces, may be the cause of chondritis. Extensive wound infection following radical mastectomy may result in costal chondritis and even osteomyelitis of the sternum.

The incidence of chondritis and perichondritis will undoubtedly be considerably diminished by the use of sulfonamides and antibio

tics to control generalized infections. Properly placed incisions will lessen the frequency of chondritis following operations for the drainage of intrathoracic or upper abdominal suppuration. When an empyema or pulmonary abscess requires drainage, it is advisable to resect a portion of rib rather than a cartilage, if such a procedure will provide an adequate approach. When the suppurative area lies beneath the cartilage, thus requiring its resection, several points should be borne in mind. If one of the upper five cartilages is to be resected, the entire cartilage should be removed. For drainage of a suppurative lesion in the middle lobe, resection of the fourth or fifth costal cartilage is usually sufficient. The costal arch, therefore, may be left intact. It is rarely necessary to resect a cartilage below the fifth for intrathoracic drainage anteriorly. Cartilage is often needlessly exposed because the surgeon does not determine the site of the costochondral junction before the rib segment is cut anteriorly. Pricking through the perichondrium with a needle or the point of a clean knife will readily and accurately show where the softer cartilage begins.

If a costal cartilage is partly resected in an infected wound, and complete removal of the remainder of that cartilage is considered undesirable, the denuded part of the cartilage should be covered by perichondrium. A simple method to accomplish this is to resect the cartilage subperichondrially for about 1 centimeter back of the line of division of the perichondrium. A curette may be used to break off pieces of the cartilage within the perichondrial envelope. The redundant perichondrium is then sutured over the exposed cut surface of the cartilage so as to cover it completely. If other tissue such as muscle is available, it may also be employed to cover the cartilage. When incisions are made in the upper abdomen, care should be taken that the perichondrium of the lower margin of the costal arch is not exposed if a suppurative focus is being drained. If cartilage is inadvertently denuded, it should be well covered with soft tissues, preferably muscles, and no drainage material should come in contact with it.

Infections of the costal cartilages are likely to become chronic unless certain fundamental principles of surgical therapy are appreciated. Although chemotherapy plays an important rôle in the treatment of chondritis, the problem is predominantly surgical. The surgeon must realize that procedures adequate for the treatment of localized infection in bone do not suffice for the treatment of chondritis. If only the involved portion of the cartilage and diseased soft tissue is removed, persistent sinus formation may occur. The surgical treatment of chondritis is subperichondrial resection of the entire involved cartilage. This principle was clearly demonstrated by Moschcowitz. The resection should extend from the bony rib to the bony sternum and not even a small bit of cartilage should be allowed to remain. Whereas this surgical procedure can be readily applied to the cartilages from the first to the fifth inclusive, the situation is far more complicated when the chondritis affects the seventh, eighth, ninth, or tenth cartilages. Since these four costal cartilages articulate with each, it is not possible to remove one of these cartilages without exposing a portion of denuded cartilage adjacent to it. For this reason radical treatment of chondritis of the seventh to the tenth cartilages involves complete resection of the costal arch with removal of all four cartilages from the rib to the medial termination. Resection of the sixth cartilage may also be necessary because of fusion with the seventh. Whereas this radical procedure is more certain of producing complete and permanent healing than a more localized cartilaginous resection, recent personal experience suggests that healing may occur if a flap of viable tissue is sutured over that portion of the adjacent cartilage which is bared of perichondrium and local penicillin therapy is employed. The less radical operation certainly justifies a trial, especially in cases in which the patient is in poor general condition, or is on the verge of cardiac or respiratory insufficiency. Resection of the costal arch results in considerable abnormal mobility of the thoracic cage temporarily, and therefore may be a serious intervention for a patient who has marked pulmonary emphysema or a serious cardiac lesion. In cartilaginous resections for infection care should be taken to avoid injury to the underlying pleura.

Infections of the costal arch of one side may extend to the opposite side, either through involvement of the xyphoid process or as a result of secondary osteomyelitis of the sternum. The xyphoid process is cartilaginous in early life but becomes partly ossified in adults. The risk of involvement of the xyphoid is greater when the structure is chiefly cartilaginous. An example of the drastic complications that may follow infection of the costal arch occurring as a sequela of the drainage of a subphrenic abscess is illustrated in a case reported by Siler. The patient developed chondritis of the left costal arch which required radical operation. The infection spread from the left to the right costal region through the cartilaginous tissue of the xyphoid process. In spite of further surgery, the process extended upward so that three more operations were required, with the result that eventually all twenty costal cartilages and the entire sternum were resected. It should be noted that the patient had serious respiratory difficulty in the postoperative period following the last procedure.

Following subperichondrial resection of a cartilage, osseous tissue may develop and result in the formation of a rigid structure (1). If the perichondrium is sacrificed in the removal of a cartilage, a permanently flaccid area in the chest wall will result. Unless care is taken to preserve the perichondrium, extensive removal of the cartilaginous structures of the chest wall will result in an undesirable instability of the thoracic cage. The formation of osseous tissue after subperichondrial resection of cartilage is well illustrated in Figure 4. Plastic procedures of varying magnitude may be required to obtain complete healing if there has been much loss of skin due to severe infection.

### OSTEOMYELITIS OF THE STERNUM

Osteomyelitis of the sternum as a result of septicemia is an uncommon occurrence (4) and constitutes only $\frac{1}{3}$ of 1 per cent of all forms of osteomyelitis. Considerably more common is involvement of the sternum as the result of direct extension of infection from adjacent areas. Osteomyelitis of the sternum is often secondary to costal chondritis. Because of the relative infrequency of operative procedures which involve direct exposure of the sternum, osteomyelitis is rarely seen as a result of infected wounds of the chest wall, except when the infection has extended from adjacent structures, such as the costal cartilages. The incidence of osteomyelitis of the sternum can therefore be drastically reduced by proper early treatment of costal chondritis. The bacteriological findings in sternal osteomyelitis and costal chondritis are similar.

The clinical picture of osteomyelitis of the sternum resembles that of involvement of other bony structures. When the infection is due to pyogenic organisms there are usually systemic signs of infection, combined with local tenderness, swelling, and perhaps fluctuation. Roentgen examination is usually of little aid in the early diagnosis of sternal osteomyelitis, but is occasionally helpful in the more chronic stage of the disease. Lateral and oblique views are most satisfactory for roentgen visualization of the sternum. The absence of changes on the roentgenogram does not exclude an extensive osteomyelitic process. If the involvement of the sternum is due to the tubercle bacillus, there may be little pain or tenderness, and a cold abscess may be the presenting sign. A tuberculous abscess overlying the sternum does not necessarily indicate involvement of the underlying bone. The tuberculous process may have arisen in the mediastinum and broken through the interspace lateral to the sternum and then extended superficially to the midline. There may be difficulty in distinguishing between chronic osteomyelitis and a tumor of the sternum. When the sternum has been destroyed by a pyogenic or neoplastic process, the pulsation of the underlying great vessels may be transmitted to the skin and closely simulate an aneurysm. Gumma of the sternum must be considered in the differential diagnosis.

When sternal osteomyelitis occurs as a result of septicemia, the mortality rate is much higher than when the infection has extended from adjacent costal cartilages. Anterior mediastinal abscess may occur in association with sternal osteomyelitis, due to the infection breaking through the posterior periosteum. Occasionally the sternal involvement

may be secondary to disease originating within the mediastinum. There is a high incidence of pulmonary complications associated with sternal osteomyelitis.

The treatment of sternal osteomyelitis consists of chemotherapy and resection of the involved portion of the sternum. If the osteomyelitis of the sternum is localized, the diseased portion may be readily removed with the rongeur. Care must be taken to avoid injury to the pleura and the underlying mediastinal structures. In some instances the posterior periosteum may be preserved. If the sternal involvement is very extensive, and especially if the patient has impaired cardiac or respiratory function, it may be advisable to perform the operation in stages in order to lessen the temporary abnormal mobility of the thoracic cage. In some cases the paradoxical motion of the chest wall is lessened as the result of the inflammation of the soft tissue. In 1 of my cases there was clinical evidence of involvement of the sternoclavicular joints, but penicillin therapy resulted in subsidence of the infection without surgical intervention. The possibility of an anterior mediastinal abscess in association with substernal osteomyelitis must be borne in mind. Care should be taken to avoid needless entry into the mediastinal tissues. Because resections of the sternum for osteomyelitis are usually incomplete, some bony regeneration occurs and provides stability of the anterior portion of the thorax after the postoperative period.

## ILLUSTRATIVE CASES

CASE 1. A. E., female, aged 64 years, had a carcinoma of the right breast complicated by diabetes mellitus and cardiac decompensation. A radical mastectomy was performed under local anesthesia in November, 1943. Infection of the operative wound with Staphylococcus aureus followed. In January, 1944, a portion of the third rib and cartilage was resected and the following month portions of the fourth and fifth ribs and cartilages were resected. It should be noted that only parts of the costal cartilages were removed in each instance. The infection of the chest wall progressed. Sulfonamide therapy and penicillin were given without avail. In March, 1944, when the patient first came under my observation at Memorial Hospital, there was an extensive suppurating wound in the anterior portion of the chest wall. There was obvious chondritis of several of the costal cartilages on both the right and left side. There was marked tenderness over the entire sternum and over both sternoclavicular joints. The patient had high fever and was obviously acutely ill. A diagnosis of multiple suppurative chondritis, osteomyelitis of the sternum, and sternoclavicular arthritis was made (Fig. 1). Because the patient was on the verge of cardiac decompensation, it was most important to avoid any respiratory difficulty such as might follow paradoxical motion caused by extensive resection of the chest wall in one stage. Multiple stage operations were therefore undertaken. Systemic and local penicillin therapy was also employed. In the course of 4 operative procedures spaced over a period of several months, most of the costal cartilages on the right, the body of the sternum and some of the costal cartilages on the left side were removed. In addition pinch grafts were employed because of the large skin defect. At the first operative procedure the soft tissue abscesses, especially the large abscess overlying the body of the sternum, were drained and some of the resected cartilages on the right side were completely excised. At the second stage operation the entire body of the sternum was resected, and at the third procedure the right costal arch was resected, with removal of the sixth, seventh, eighth, ninth, and tenth costal cartilages. Following these procedures the entire area healed with the exception of two persistent sinuses, one near the lower end of the manubrium and the other leading to the fourth left costal cartilage. This costal cartilage was then removed in its entirety and healing of the entire wound finally occurred (Fig. 2). There was good stability of the chest wall without any paradoxical motion on respiration.

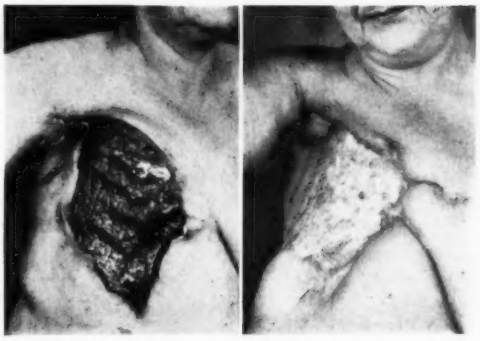

Fig. 1, left. Infected mastectomy wound with costal chondritis and sternal osteomyelitis.

Fig. 2. Healed wound after multiple operative procedures for bilateral costal chondritis with sternal osteomyelitis.

If the infected costal cartilages had been radically removed at an early stage of the thoracic wall suppuration, it is quite likely that extensive spread of the infection, especially into the body of the sternum and across to the opposite side, might have been avoided.

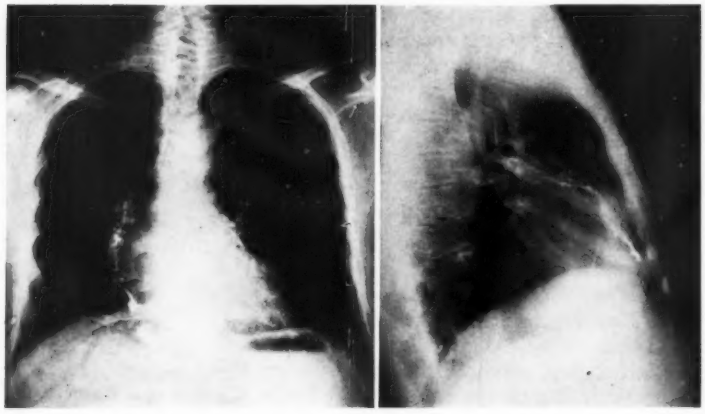

Fig. 3. a, left, Posteroanterior film. b, Lateral film. Lipiodol injected into sinus at lower right border of sternum has entered the right middle lobe through a previously unsuspected bronchocutaneous fistula. There is bronchiectasis of the right middle lobe. Some lipiodol has spilled over into the left lung.

Failure to appreciate the importance of complete removal of an infected costal cartilage was at least partly responsible for the serious situation which developed.

CASE 2. F. McN., female, aged 19 years, gave a history of cough and chest pain of 11 days' duration. The onset began with a severe sore throat, fever, dysphagia, and progressive prostration. Substernal pain was noted 5 days later. The cough was productive of rusty sputum. Sulfonamide therapy had been given without response. On admission to Kings County Hospital the patient was acutely ill, markedly dyspneic, somewhat disoriented, and icteric. There were dullness and râles at the bases of both lungs. A soft, fluctuant, raised area was present over the sternum at the junction of the manubrium and gladiolus. The cardiac pulsation was transmitted through the mass. Three days after admission crepitation was evident at the junction of the manubrium and gladiolus. Aspiration of the abscess revealed thin, light brown, nonodorous pus which cultured hemolytic streptococci. On incision and drainage an abscess cavity overlying the lower portion of the manubrium and upper portion of the gladiolus was found. There was complete interruption of the continuity of the sternum at the site of the synchondrosis. A fairly large anterior mediastinal abscess communicated directly with the site of involvement of the sternum. A small amount of the involved manubrium and gladiolus was removed with a rongeur. Although the second costal cartilage on each side projected into the abscess cavity, these two cartilages were not completely removed at this time because of the patient's very poor condition. Following operation the wound drained profusely. The patient showed slight signs of improvement, but the blood culture continued to be positive for hemolytic streptococci in spite of continued penicillin and sulfonamide therapy. The liver was enlarged and tender and the icterus progressed. Two days following operation the patient coughed up a large amount of bright red blood and died very suddenly. It is thought that the bleeding occurred from the rupture of a suppurative intrapulmonary focus, because no blood appeared in the operative wound. No autopsy was obtained.

Fig. 4. X-ray film taken 2 years after resection of the costal arch shows bone formation at the site of the previously resected cartilages.

This case is one of osteomyelitis of the sternum as part of a general septicemia. The destruction of the sternum was unusually rapid. The pulsation of the abscess overlying the sternum was so pronounced that some observers thought it might be an aneurysm. The anterior mediastinal abscess and pneumonia which were present in this case are two of the common complications of an osteomyelitis of the sternum and are associated with a high mortality. Death in this case was undoubtedly due to uncontrolled suppurative foci elsewhere. Osteomyelitic involvement of the sternum at the synchondrosis between the manubrium and gladiolus is uncommon.

CASE 3. B. M., male, aged 51 years, was stabbed in the chest near the junction of the second costal cartilage and the left border of the sternum. When admitted to the thoracic service of Kings County Hospital a week after injury, the patient was dyspneic, cyanotic, and disoriented. The wound discharged a foul pus. There was fluid in the left pleural cavity and within the pericardium. An abscess of the chest wall at the site of the stab wound was incised and drained. The culture from this abscess grew out Staphylococcus aureus. Thoracentesis of the left pleural space yielded thick pus containing staphylococci, and the bloody fluid obtained on pericardial tap also yielded hemolytic Staphylococcus aureus. The empyema and suppurative pericarditis were treated by aspiration and direct instillation of penicillin into the pleural and pericardial cavities respectively. The patient's condition improved progressively. The empyema and pericarditis cleared without surgical intervention, but the original infected stab wound continued to drain. Probing of this wound demonstrated the presence of necrotic bone, and therefore operation was undertaken for suppurative osteomyelitis and chondritis. The partly infected second costal cartilage was completely removed and the involved portion of the sternum in the same region was resected with a rongeur. There was no evidence of a mediastinal abscess. Following this procedure the patient made an uneventful recovery and the wound was healed a little over a month later.

This patient had an extensive staphylococcus infection involving two serous cavities which responded to penicillin and sulfonamide therapy. The local wound failed to heal, however, because of the involvement of bone and cartilage. Following surgical removal of the osteomyelitic portion of the sternum and the entire involved cartilage, healing occurred without further incident.

CASE 4. A. K., male, aged 38 years. When the patient was first seen at Bellevue Hospital in December, 1940, he gave a history of having had repeated abscesses in the right lower anterior thoracic region for 19 years. Although the abscesses were opened surgically on a few occasions, they usually ruptured spontaneously and sinuses persisted for varying periods of time. In December, 1940, there was a large, fluctuating area overlying the right costal arch with skin necrosis. A large superficial abscess was drained. Lipiodol injection of the sinus tract revealed an abscess cavity extending beneath the costal arch, but not communicating with the pleural cavity. In January, 1941, a radical resection of the entire costal arch was performed, with removal of the sixth through the tenth costal cartilages inclusive, from the rib to the sternum. The postoperative course was uneventful, but the wound granulated in slowly because of the large skin loss caused by the previously neglected superficial abscess. In December, 1941, the patient complained of tenderness and pain in the region of the lower end of the sternum. Roentgenograms suggested osteomyelitis of the lower sternum. Operation was again performed and the lower end of the sternum and some regenerated bone at the site of the previously resected cartilages were removed. A sinus tract was followed inward and a chronic abscess was found overlying the upper portion of the pericardium. Pathological examination of the wall of the abscess showed only chronic inflammation. All pathological material obtained during the various operative procedures showed nonspecific inflammation. Tuberculosis was never demonstrated. The operative wound healed gradually except for one small sinus. About this time the patient had recurrent attacks of cholecystitis. In August, 1942, cholecystectomy was performed for cholecystitis and cholelithiasis. Since that time, the patient has had no further symptoms referable to the biliary tract.

The small sinus which persisted in the anterior thoracic region would sometimes close for several weeks, and then reopen spontaneously. The patient also had some cough productive of mucopurulent sputum, and several attacks of pneumonitis. Lipiodol injected into the sinus entered the tracheobronchial tree and demonstrated the presence of a bronchocutaneous fistula (Fig. 3). Bronchograms showed bronchiectasis of the right middle lobe. Therefore in May, 1944, another operation was undertaken. Through a posterolateral incision on the right the pleural cavity was entered. The middle lobe was found to be a dense, fibrotic mass. It was firmly adherent to the mediastinum and pericardium at the site of the old mediastinal abscess. The middle lobe communicated with the chest wall sinus. A middle lobe lobectomy was performed. There was marked infiltration of the anterior thoracic wall in the region of the thoracic sinus, and several cubic centimeters of thick, yellow, nonodorous pus was present. The operative wound healed by primary union, except at the site of drainage. This area did not heal permanently for nearly 4 months. All wounds have remained healed; the patient now, 2½ years later, has no cough or sputum, and is in excellent condition.

This case is an example of infection of the costal cartilages and sternum secondary to chronic disease of the anterior mediastinum. Tuberculous lymphadenitis may have been the underlying factor, although the etiology was never proved. There was considerable calcification present in the hilar lymph nodes. The infection of the structures of the chest wall recurred as long as the underlying intrathoracic suppuration remained. The pulmonary involvement with bronchocutaneous fistula further complicated the situation.

## SUMMARY

1. If any portion of one of the upper five costal cartilages is the seat of a suppurative chondritis, surgical removal of the entire cartilage from rib to sternum is indicated. If no chondritis is present but a portion of the normal costal cartilage has been resected in an infected wound, the cut surface of the cartilage should be covered by perichondrium.

2. If any portion of the sixth, seventh, eighth, ninth, or tenth costal cartilages is the seat of suppurative chondritis, the entire involved cartilage or cartilages should be removed and a flap of perichondrium and muscle sutured over the area or areas of adjacent cartilages denuded of perichondrium. Local penicillin therapy should be employed. Should these conservative measures fail or should the initial involvement of the costal arch be fairly extensive, radical removal of the entire arch is indicated.

3. Osteomyelitis of the sternum can usually be avoided by adequate early treatment of the infection in the adjacent costal cartilages. Most infections of the sternum begin in the adjacent structures and extend to the sternum secondarily. If osteomyelitis of the sternum develops, only the diseased portion of bone need be removed.

4. If extensive osteomyelitis of the sternum exists, the operative procedure for removal of the diseased bone should usually be done in stages to minimize serious abnormal mobility of the chest wall. The possibility of an anterior mediastinal abscess must be borne in mind.

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# THE ESTIMATION OF ACUTE BLOOD LOSS BY THE TILT TEST

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THE fundamental therapeutic problem in hemorrhage, other than direct arrest of bleeding, is the determination of the amount of blood required to restore circulatory volume to normal.

An acute blood loss exceeding 40 per cent is likely to be fatal (1, 2). Lesser grades of bleeding may be compensated by vasoconstriction, hemodilution and maintenance of cardiac output through tachycardia. Replenishment of proteins and cells follows more slowly (4).

In the absence of acute bleeding, reductions as great as 80 per cent in hemoglobin and 60 per cent in serum proteins may be encountered in ambulatory patients who present few evidences of critical illness. In hemorrhage, therefore, the major hazard is a decrease in circulatory volume which exceeds the limits of compensability. Attendant disturbances in oxygen carrying capacity, blood viscosity and osmotic pressure are not directly responsible for fatalities. A successful outcome depends fundamentally on the maintenance of an adequate blood volume, regardless of etiology, location, or surgical remediability of the hemorrhage.

Direct measure of blood loss rarely is possible. The patient's concept of the quantity is unreliable, and vomited or defecated blood is diluted with variable amounts of other fluids. Retention within body cavities or tissues may conceal all external evidences of bleeding (7).

The appraisal of hemorrhage by the red count, hemoglobin and hematocrit values is subject to two sources of error. These values are reduced by preexisting anemia, despite negligible acute blood loss, and are unaffected by massive hemorrhage until hemodilution has occurred.

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Pulse rate and blood pressure also are used as criteria of severity (6). Frequently, however, no individual base line standards are available. Pulse rates are influenced by fear and by antecedent disease, particularly in the heart. Blood pressure levels within normal limits may represent materially reduced values for the hypertensive patient, while relatively low levels have lessened significance in the hypotensive person.

Ideally it would be desirable to estimate the severity of hemorrhage by direct measurement of the remaining blood volume(7). However, this procedure has not found common use in the three decades which have elapsed since the introduction of dye methods, apparently because it is too time-consuming or technically difficult for routine clinical practice.

Finally, where the presence of obvious shock indicates a hemorrhage of major proportions, the amount of blood to be given still remains the fundamental problem.

The amelioration of frank hemorrhagic shock by the head-down position is a matter of common experience. Less familiar perhaps, is the contrary phenomenon that hemorrhage patients who are able to maintain a relatively normal blood pressure while lying flat, often may be thrown into shock on sitting or standing up (8, 11). The frequency with which these effects may be observed suggested the possibility that cardiovascular reactions to change in posture could be related quantitatively to blood loss and diminished circulatory volume. Accordingly, determinations were made under standardized conditions of the normal response to tilting, and its modification by old age, cardiovascular disease, and anemia. Subsequently, the tilting reactions which followed controlled acute blood loss of varying amount were compared with those manifested by a series of patients who were admitted because of recent gastrointestinal hemorrhage.

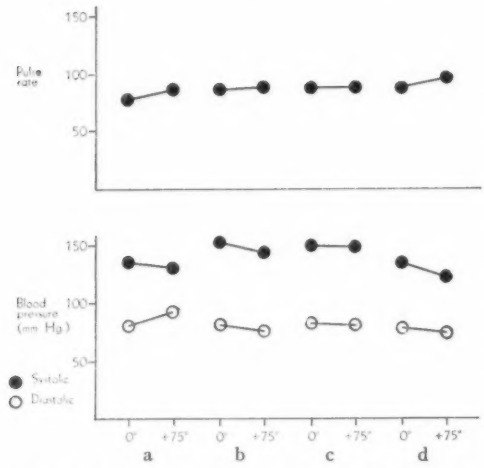


Fig. 1. Responses to tilting in normal subjects and in the presence of old age, cardiovascular disease, and anemia. a, Normal group, 25 subjects; b, aged group, 13 subjects, average age 80 years; c, cardiac group, 11 subjects; d, anemic group, 11 subjects, average hemoglobin 7.8 grams.

### TILT TEST

The response to tilting was determined as follows: The subject was moved in a supine position to the x-ray department of the hospital and placed horizontally on the fluoroscopy table. Pulse rate and blood pressure measurements were made and repeated until constant. Stable readings were obtained within three trials. The table then was tilted to minus 30 degrees, plus 30 degrees and plus 75 degrees and similar measurements carried out. Finally, the subject was maintained in a position of plus 75 degrees for 3 minutes and the pulse rate and blood pressure were determined at intervals of 1 minute, unless the occurrence of syncope dictated the interruption of the test.

The responses of practical significance were the ones observed at plus 75 degrees as compared with those at 0 degrees.

*Responses to tilting in normal subjects.* The responses of a group of 25 normal subjects varying in age from 18 to 46 years (Fig. 1a) are typical of those described in standard texts of physiology (1). Tilting was marked by a small, consistent cardiac acceleration, slight fall in systolic pressure and a moderate rise in diastolic pressure. No unusual subjective changes were reported.

*Responses to tilting in the aged.* Observations were made on a group of 13 individuals with a mean age of 80 years (Fig. 1b). The group differed from the normal in displaying a higher mean level of pulse rate and systolic pressure while supine. On tilting, changes in pulse rate were not marked. The blood pressures varied moderately, averaging a small net systolic and diastolic fall.

*Responses to tilting in the presence of cardiovascular disease.* Reactions to tilting were studied in a group of 11 individuals suffering from cardiovascular diseases (Fig. 1c). The majority of these patients belonged in the arteriosclerotic or hypertensive classifications and were decompensated in varying degree. The supine levels of pulse and systolic pressure were somewhat above normal. On tilting, all circulatory changes were small and inconstant.

*Responses to tilting in the presence of chronic anemia.* Tilting responses were measured in 13 patients presenting anemia as an intercurrent feature of a variety of disease conditions, including metastatic carcinoma, nephritis, subacute bacterial endocarditis and metrorrhagia (Fig. 1d). The hemoglobin value varied from 5 to 11 grams, the average being 7.8 grams.

TABLE I.—SUPINE PULSE RATES FOLLOWING ACUTE BLOOD LOSS AS COMPARED WITH THE RANGE OF VARIATION IN NONBLEEDING PATIENTS

| | Normal | Aged | Cardiac | Anemic | Total non-bleeding | Venesection 5–9 c.c. kg. | Venesection 9–14 c.c. kg. | Venesection 12–21 c.c. kg. | Recent gastro-intestinal hemorrhage |
|---|---|---|---|---|---|---|---|---|---|
| No. of subjects | 25 | 13 | 11 | 13 | 56 | 19 | 11 | 5 | 11 |
| Average rate | 78 | 87 | 89 | 87 | 84 | 81 | 85 | 95 | 103 |
| S.D.* | 12 | 19 | 16 | 15 | 15.7 | 15 | 23 | 15 | 24 |

*Standard deviation, corrected for small samples.

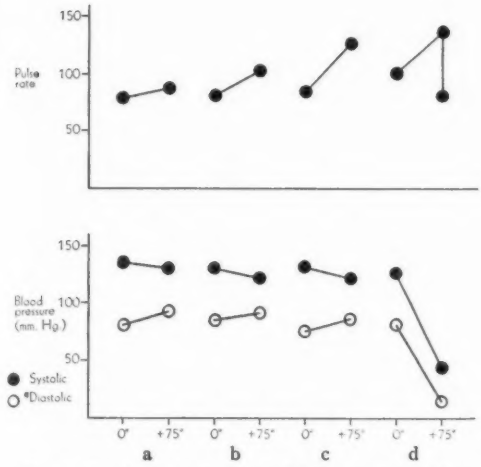


Fig. 2. Dominant responses to tilting in normal subjects before and subsequent to rapid blood loss by venesection. a, Normal, 25 subjects; b, blood loss, 5 to 9 c.c./kg. primary reaction, 17 of 19 subjects; c, blood loss, 9 to 14 c.c./kg. primary reaction, 9 of 11 subjects; d, blood loss, 14 to 21 c.c./kg. secondary reaction, 4 of 5 subjects.

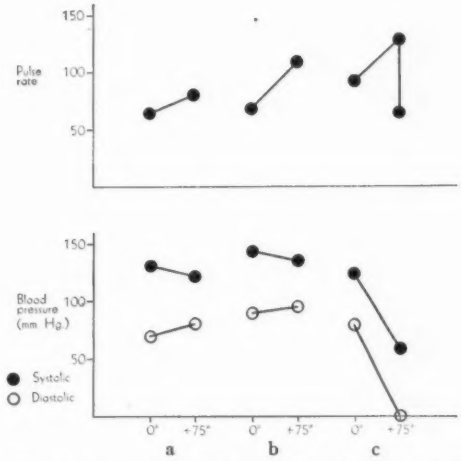


Fig. 3. Progression of tilting response in same subject from primary to secondary type with increasing blood loss. Subject: T, weight 73 kilograms. a, Before venesection; b, blood loss, 1000 c.c., primary reaction; c, blood loss, 1500 c.c., secondary reaction.

The increase in pulse rate with tilting was comparable to that noted in normal individuals but the actual rates were higher. A fairly consistent but moderate drop in systolic pressure was observed. Diastolic variations were inconstant, averaging a small net fall. One subject complained of slight dizziness upon being maintained in the plus 75 degrees position. Abnormality of response roughly paralleled the severity of the anemia.

The trend suggests that the stress of tilting is less adequately compensated in the presence of anemia, but the observed variations were not statistically significant. This trend may be associated with the decreased peripheral resistance and augmented resting cardiac output observed in anemia, manifestations which can be corrected by transfusion (2).

*Responses to tilting following rapid removal of known quantities of blood.* Tilting responses were measured in three groups of normal individuals before and immediately following rapid removal of blood by venesection. The subjects consisted of blood donors, residents, interns, and hospital orderlies who volunteered their services. Five to 9 cubic centimeters per kilogram were withdrawn from the 19 subjects in group I, 9 to 14 cubic centimeters per kilogram from the 11 subjects in group II, and 14 to 21 cubic centimeters per kilogram from the 5 subjects in group III, corresponding respectively to 500, 1000, and 1500 cubic centimeters for the average individual. The time which elapsed between start of venesection and completion of posthemorrhagic tilting varied from 30 minutes to 1 hour depending on the quantity of blood withdrawn.

During and following venesection, blood pressures were maintained within normal limits and no unusual subjective reactions were reported, as long as the patients remained in the supine position. Comparison of pulse rates with those recorded prior to bleeding indicated that cardiac acceleration was not marked, averaging plus 3, plus 7, and plus 17 beats per minute respectively for the three groups. The actual pulse rates failed to show statistically significant differences in range from those observed in nonbleeding groups (Table I).

On tilting, two types of reaction were observed. The primary type and the dominant response in which the blood loss did not exceed 14 cubic centimeters per kilogram, was char-

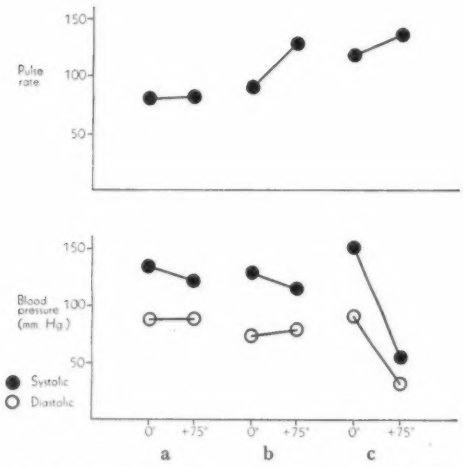


Fig. 4. Reactions to tilting in 11 patients admitted for recent gross gastrointestinal bleeding. a, Normal response, 3 subjects, hematocrit (av.) 37 per cent; b, primary reaction, 2 subjects, hematocrit (av.) 30 per cent; c, secondary reaction, 6 subjects, hematocrit (av.) 29 per cent.

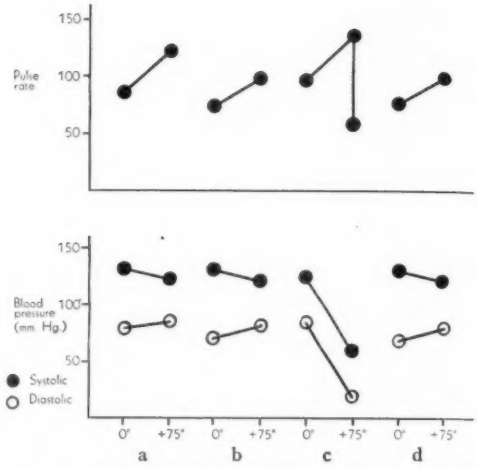


Fig. 5. Tilting responses following acute blood loss (1000 to 1500 c.c.) with return to normal on hemodilution. Time interval: 24 to 72 hours. a, Primary reaction of tachycardia, 5 subjects, hematocrit (av.) 46 per cent; b, return to normal following hemodilution, hematocrit (av.) 38 per cent; c, secondary reaction of syncope 2 subjects, hematocrit (av.) 49 per cent; d, return to normal following hemodilution, hematocrit (av.) 38 per cent.

acterized by a well marked cardiac acceleration without significant variation from the systolic pressure drop and diastolic rise associated with tilting normal subjects. The cardio-acceleration on tilting was proportional to the extent of blood loss and averaged 20 beats per minute in group I, 42 per minute in group II (Fig. 2b and 2c). Those individuals who had lost the larger quantities of blood showed somewhat increased respiratory depth and definite pallor.

A secondary type of reaction to tilting was observed in 2 of the 19 subjects in group I, 2 of the 11 in group II, and 4 of the 5 in group III. In these individuals, maintenance in the plus 75 degree position was accompanied by marked tachycardia, air hunger, and faintness, succeeded by a rapidly progressive fall in blood pressure to shock levels, slowing of the pulse rate, ashen pallor, cold sweat, unconsciousness, and transient muscular twitchings (Fig. 2d). This type of response was reversible immediately on lowering the subject to the supine position, although slow pulse rates sometimes persisted for periods up to several hours.

The primary type of reaction appears to represent a blood volume deficit which is still compensable under the stress of tilting. The secondary response occurs when this additional stress causes a break in compensation. The relation is illustrated in Figure 3 which depicts the progression from the primary to secondary response in the same individual on withdrawl of an additional 500 cubic centimeters of blood following an initial venesection of 1000 cubic centimeters.

The mechanism responsible for posthemorrhagic syncope on tilting to the upright position is not entirely clear. However, a change from supine to upright posture lowers the cardiac output in normal individuals approximately 25 per cent, presumably due to reduced venous return secondary to pooling of blood in the extremities (10). This reduction, superimposed on the diminished venous return due to hemorrhage, may produce a net fall in intra-atrial pressure below the critical level for ventricular filling, with rapidly progressive circulatory failure, cerebral anemia and vasovagal syncope as a consequence.

*Hemodilution and tilting responses.* On the assumption that reduced circulatory volume is responsible for the abnormal responses to tilting observed in controlled blood loss, then

TABLE II.—THE MEAN DIFFERENCES (D) IN PULSE RATE AND BLOOD PRESSURE VALUES FOLLOWING TILTING IN BLEEDING AND NONBLEEDING SUBJECTS

| Group | Normal | Aged | Cardiac | Anemic | Total non-bleeding | Venesection 5–9 c.c. kg. | Venesection 9–14 c.c. kg. | Venesection 14–21 c.c. kg. |
|---|---|---|---|---|---|---|---|---|
| No. of subjects | 25 | 13 | 11 | 13 | 56 | 17† | 9† | 5 |
| d (pulse) | +9 | +2 | 0 | +8 | +6 | +20 | +42 | +36‡ |
| S.D.* | 7.0 | 5.5 | 5.4 | 8.6 | 7.8 | 10 | 8.3 | 8.9 |
| No. of subjects | 25 | 13 | 11 | 13 | 56 | 17 | 9 | 4§ |
| d(systolic BP) | −5 | −9 | −1 | −13 | −6 | −9 | −10 | −82 |
| S.D.* | 8.1 | 12 | 12 | 17 | 11 | 10 | 13 | 32 |
| No. of subjects | 25 | 13 | 11 | 13 | 56 | 17 | 9 | 4 |
| d(diastolic BP) | +12 | −5 | −1 | −4 | +4 | +6 | +10 | −66 |
| S.D.* | 9.3 | 7.7 | 7 | 11 | 11 | 8 | 7.1 | 27 |

*Standard deviation, corrected for small samples.
†Two secondary reactors excluded to permit comparison of homogeneous groups of primary reactors.
‡Based on pulse rates prior to bradycardia.
§One primary reactor excluded to permit comparison of a homogeneous group of secondary reactors.

replenishment of circulatory volume through compensatory hemodilution should be associated with return of tilting responses to normal.

Accordingly, a study was made of the relation between successive tilt test results and hemodilution in 7 subjects subsequent to withdrawal of 1000 to 1500 cubic centimeters of blood. The reduction in the hematocrit was used as the index of hemodilution (4).

A return to normal tilting responses required from 24 to 72 hours and was associated with a drop in the average hematocrit value from 47 to 38 per cent (Fig. 5). The apparent therapeutic paradox of a patient who improved as the hematocrit fell was seen in each instance.

*Responses to tilting in gastrointestinal hemorrhage.* The tilt test was carried out in a group of 11 individuals admitted because of a history of recent gross gastrointestinal hemorrhage, but free of obvious evidences of shock at the time of initial observation.

The responses of 3 individuals were within normal limits and no emergency transfusions were given. All recovered uneventfully. One of the 3 received 500 cubic centimeters of blood prior to discharge to accelerate the treatment of a secondary anemia.

Two patients developed reactions similar to the primary response observed following controlled blood loss. One of the 2, a woman aged 48 years, was given 1500 cubic centimeters of blood. A subsequent gastric resection was performed without incident. The other, an acutely alcoholic male, aged 32 years, developed delirium tremens shortly after admission. Because of the likelihood that an abnormal tilting response had been produced by the anesthetic and vasodilator actions of the alcohol, blood was withheld, and intensive treatment with intravenous fluids, glucose, insulin, and vitamins was substituted. Recovery was uneventful.

The remaining 6 patients manifested secondary reactions with reductions in blood pressure to shock levels. They were given an average of 2000 cubic centimeters of blood. Five recovered satisfactorily. The sixth, whose source of hemorrhage was a ruptured esophageal varix, ultimately died of hepatic failure.

## COMMENTS

The standard deviations of the values for the circulatory changes observed in this study (Table II) indicate that significant differences in the responses to tilting were associated only with acute blood loss exceeding 9 cubic centimeters per kilogram.[1]

The actual limits of change in pulse rate and blood pressure under the conditions of the test were found to be somewhat narrower both in normal persons and in those suffering from nonhemorrhagic diseases than the ranges which have been reported when similar classes

[1]True orthostatic hypotension as a rare but possible cause of abnormal tilting responses may be ruled out by history. Abnormal responses are produced also by morphine (3) and general anesthetic agents (5).

of individuals have been made to stand up (9). This difference may be due to the essentially passive nature of the change in position produced by tilting. In contrast, the act of standing is complicated by the necessity for complex voluntary motor activity. The expenditure of muscular energy which the act requires may overtax the limited resources of certain patients. Whatever the explanation, the data obtained to date suggest that acute blood loss is manifested more specifically by the response to tilting than by the reaction to standing up.

The variation in ability of normal individuals to compensate for blood loss is compatible with the expected scatter in distribution of responses to any physiological stress. However, certain circulatory changes on tilting from 0 to 75 degrees were sufficiently characteristic of definite grades of blood loss for their selection as potentially useful standards:

1. The pulse rate increase on tilting individuals in the normal, aged, cardiovascular or anemic groups never exceeded 25 beats per minute. It always exceeded this figure following a blood loss of 1000 cubic centimeters. An increment of 30 beats or more was noted in 10 of 11 subjects in this latter group, while only 1 of 19 subjects who had lost 500 cubic centimeters manifested a similar rise.

2. The secondary syncopal reaction was observed in 4 of 5 individuals who lost an average of 1500 cubic centimeters of blood, while it occurred in but 4 of 30 deprived of 500 to 1000 cubic centimeters, and in none in whom acute blood loss had been absent.

3. Within the extremes of the range of blood loss explored, the manifestations of shock were noted in no subject prior or subsequent to tilting as long as the supine position was maintained.

## CONCLUSIONS

From the total of these observations certain tentative guides to therapy seem applicable to the patient who has had a hemorrhage.

1. An increase in cardiac rate less than 25 beats per minute on tilting, in the absence of a syncopal reaction, indicates either a negligible or a compensated acute blood loss. Transfusion is not required as an emergency therapeutic measure, although the degree of anemia or possibility of recurrent bleeding may suggest its desirability as a prophylactic means.

2. An increase in cardiac rate on tilting of 30 beats or more per minute over that observed in the supine position suggests a blood volume deficit of 9 to 14 cubic centimeters per kilogram and a probable transfusion requirement of 1000 cubic centimeters.

3. The occurrence of a syncopal reaction to tilting suggests a probable blood volume deficit of 14 to 20 cubic centimeters per kilogram and the advisability of a transfusion of 1500 cubic centimeters.

4. The presence of shock in patients maintained in the supine position indicates a probable blood volume deficit in excess of 20 cubic centimeters per kilogram and a need for transfusion of 2000 cubic centimeters or more. This figure agrees with the average quantity found to restore blood volume to normal in studies of hemorrhagic shock by the dye method (7).

5. The hematocrit value bears no direct relationship to the magnitude of recent hemorrhage. A falling hematocrit level indicates only that hemodilution is occurring, not the continuation or recurrence of hemorrhage.

Due to the normal variation in response to hemorrhage, it is estimated that in 15 per cent of patients the transfusion requirements postulated will exceed the minimum needed to prevent further hemodilution and restore the circulatory volume to normal. This occasional excess is considered to represent a reasonable margin of safety for the majority of cases.

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# CIRCULATORY AND RESPIRATORY DISTRESS FROM EXTREME POSITIONS ON THE OPERATING TABLE

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THE proper position of the patient on the operating table in conjunction with well balanced anesthesia should facilitate the surgical procedure and allow only minimal interference with the physiological processes of respiration, circulation and neurogenic control. In many instances, however, the position requested is so extreme that few normal conscious individuals can voluntarily assume such for as long as 30 minutes. If the anesthesia is not too profound the majority of anesthetized patients will temporarily adjust themselves to these physiologically poor positions by the utilization of compensatory vasomotor and respiratory changes. Many individuals with systemic disease are unable to make adequate adjustments and within a short time manifest signs of distress by either respiratory or cardiovascular changes or a combination of the two. From the standpoint of the proper functioning of these two systems the supine-horizontal position is the one best tolerated by the anesthetized patient.

The studies of Case and Stiles on the effects of surgical positions on vital capacity show that reductions of about 15 per cent occurred in lithotomy, Trendelenburg, kidney, and jackknife positions (3). If such a decrease in vital capacity occurs in unnarcotized subjects within 3 minutes after being placed in these positions, greater changes in the same direction may occur over longer periods of time. Since vital capacity studies presuppose a conscious subject the test is not directly applicable to anesthetized patients. In our own studies of the effects of different positions upon the tidal volumes of anesthetized patients we have noted changes in the residual air volumes which are in keeping with the changes reported by Case and Stiles for vital capacity. If the patient with a low vital capacity due to systemic disease is placed in a position which further reduces his respiratory volume, serious complications may arise.

In normal breathing, the thoracic cage enlarges in all directions except posteriorly. With the deeper planes of anesthesia the intercostal part of respiration tends to be abolished and most of the load of breathing is shifted upon the diaphragm. The excursion of the diaphragm during the expiratory phase is impaired by the loss of abdominal muscle tone. If during such conditions, the patient is so placed that he rests upon his lower ribs either in the prone or lateral position, respiratory embarrassment will be evidenced by either rapid and shallow breathing or apnea and by secondary circulatory changes. Abnormal shallow breathing has been shown to result in incomplete ventilation which in turn may cause hypoxemia (5). Moreover, any factors which cause elevation of the diaphragm such as increased abdominal pressure due to abdominal packs, tight abdominal binders, flat prone or steep Trendelenburg positions predispose to the development of atelectasis during or following the surgical procedure.

Circulatory distress most often begins as the result of venous and capillary stasis in dependent extremities or as the result of the splanchnic pooling of blood. There are four factors which normally aid the venous return in raising the blood against gravity. If any or several of these factors fail, the accumulation of blood in the dependent parts is likely to occur.

The first factor of venous return is the impetus given the blood by the contraction of the left ventricle. Myocardial depression may result directly from high concentrations of most any of the anesthetic drugs when used for profound anesthesia. It may also occur as the result of hypoxia accompanying respi-

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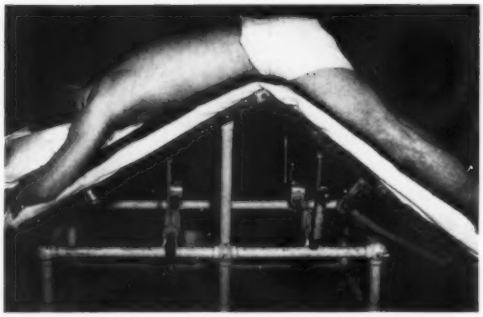

Fig. 1. Jackknife position without blocks beneath pelvis.

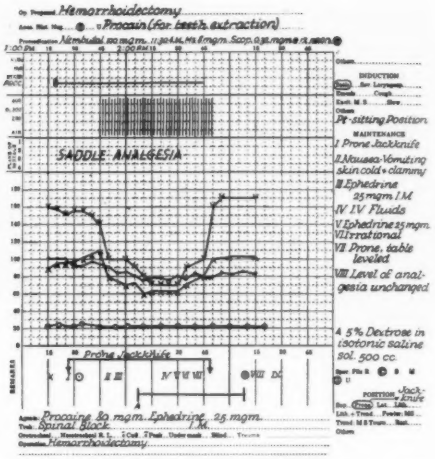


Fig. 2. Circulatory distress from acute jackknife position. Case No. 2751.

ratory distress or secondary to low arterial pressure.

A second factor is the support of the vein walls due to the tonus of the abdominal and limb muscles. The intermittent contractions of the skeletal muscle fibers which, in conjunction with the valves of the veins, propel the blood in the upward direction is decreased and often abolished by anesthetic drugs.

A third factor is the suction and force-pump action on the great veins produced by normal respiratory movements. This function of breathing is reduced by: (a) profound anesthesia, (b) interference with intercostal activity due to pressure upon the lateral or ventral surface of the thorax, and (c) interference with diaphragmatic excursion as the result of increased intra-abdominal pressure.

As a fourth factor, the vasopressor and capillary tonus mechanisms control the caliber of the venocapillary vessels of the splanchnic area and prevent the venous blood from becoming pooled in this area at the expense of the effective circulatory volume in other regions. Autonomic response to surgical manipulation or to severe pressure occasioned by the acute angulation of the body in the jackknife or kidney position may produce stagnation of blood in the splanchnic area. Low oxygen tensions, high carbon dioxide tensions and various anesthetic agents will dilate capillaries and venules with the same result.

As long as the deeply anesthetized patient is in the supine horizontal position the effects of gravity are annulled but at least three of the four compensatory controls are depressed so that changes from the horizontal position may be fraught with serious complications.

Records showing the harmful effects of improper position are not always clear cut because of the complicating factors of hemorrhage, trauma, obstructed airway, anesthetic overdose, procaine reactions, etc., which in themselves cause marked variations in respiration and circulation. Leveling of the table will usually relieve the distress of malposition more effectively than a blood transfusion.

Figure 1 demonstrates the jackknife position. Here, it is noted that the dependent position of the legs, arms, and head would tend to reduce the venous return to the heart. If to this pull of gravity is added the effects of spinal anesthesia or deep general anesthesia with the accompanying loss of skeletal muscle tonus and sympathetic vasomotor control a venous and capillary stasis would occur. Costal excursion is reduced by pressure on the ventral surface of the thorax. The increased intra-abdominal pressure resulting from the ventral compression of the abdomen and the weight of the viscera in the head-low position interfere with the respiratory exchange and the pumping action of the diaphragm as an aid in venous return.

The anesthesia record shown as Figure 2 is that of a 58 year old male with a physical

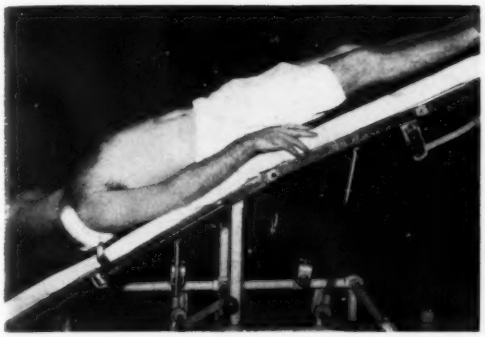

Fig. 3. Steep Trendelenburg position.

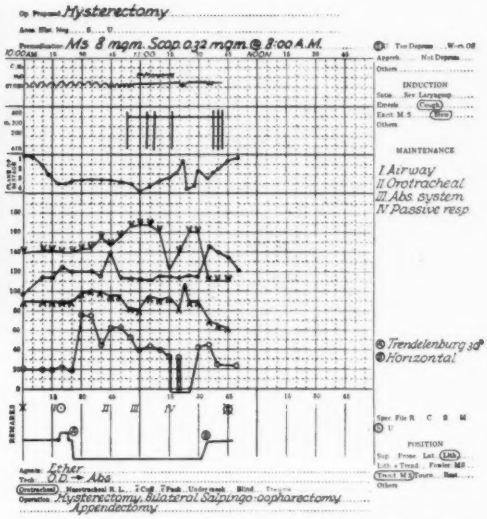


Fig. 4. Respiratory distress associated with steep Trendelenburg position. Case No. 2939.

status of 1. Previous testing had shown the patient not to be hypersensitive to procaine. Eighty milligrams of this drug were injected at the fourth lumbar interspace with the patient in the sitting position so that saddle analgesia for a hemorrhoidectomy would be obtained. Five minutes later the patient was placed in the prone position and 10 minutes later he was flexed to the extreme jackknife. Twenty minutes after assuming the latter position the blood pressure dropped markedly and the skin became cold and clammy. The patient became nauseated and vomited. The level of the analgesia did not rise above 12 dorsal at any time during the course of the operation. The administration of an infusion, 25 milligrams of ephedrine intramuscularly, and oxygen gave no significant improvement. When the table was raised to the horizontal position there was a prompt return of systolic diastolic, and pulse pressures to comparatively normal levels. We have noted similar distress when only local infiltration anesthesia was being used and similar improvement in these cases by leveling the table.

Our recommendations for procedures which are best accomplished with the patient in this position are: (a) use small pillows or blocks under the pelvis and upper chest in order to minimize interference with respiratory exchange; (b) if general anesthesia is employed, avoid the deeper planes; (c) flex the table only far enough to allow satisfactory exposure of the operative site.

Steep Trendelenburg position is demonstrated by Figure 3. The diaphragm during the inspiratory phase must lift the weight of the abdominal contents. Profound anesthesia which is accompanied by partial or complete intercostal paralysis, therefore, would leave an inhibited diaphragm to carry the load of breathing. The decrease of the functional residual air in the Trendelenburg position suggests that changes in intrapleural pressure occur in this position which tend to make respiration more difficult and impair the return of venous blood to the heart (1). In the head-down position, the cardiac output per minute and per beat is decreased and the arteriovenous oxygen difference increased over the values obtained with the patient horizontal (4).

It is unlikely that the circulation through the brain is increased in patients in the head-down position. Venous and cerebrospinal fluid pressures are increased in the brain thus interfering with the inflow of the arterial blood into the rigid confines of the cranial vault. Animal experimentation has shown that this results in an initial slowing of the circulation followed by a return to normal (7).

Obese individuals do not tolerate steep Trendelenburg positions. In Figure 4, the record shows marked respiratory distress

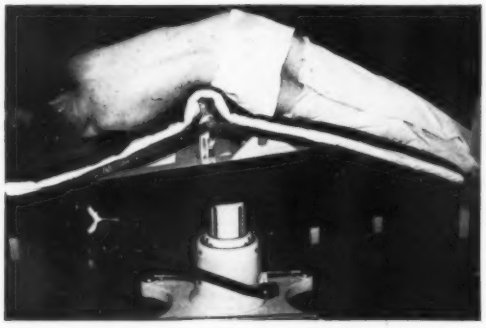

Fig. 5. Kidney or lateral jackknife position.

beginning immediately after the patient was so placed. The depth of anesthesia was varied during the next hour without relief of symptoms. The distress continued until the table was brought back to the horizontal plane.

Our suggestions for this position would be: (a) do not use a 30 degree Trendelenburg position if the procedure can be done adequately with one of only 15 degrees; (b) do not use this position to compensate for blood loss; (c) if the extreme position is indicated, limit its use to that part of the surgical procedure which demands it. The reflex abdominal pos-

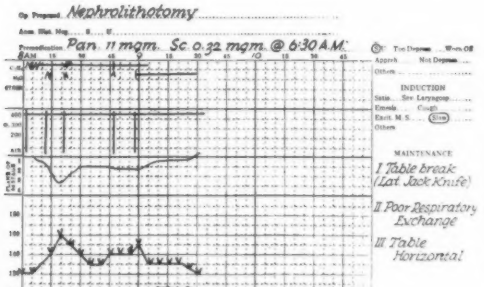


Fig. 7. Respiratory embarrassment in lateral jackknife position for nephrolithotomy. Case No. 2517.

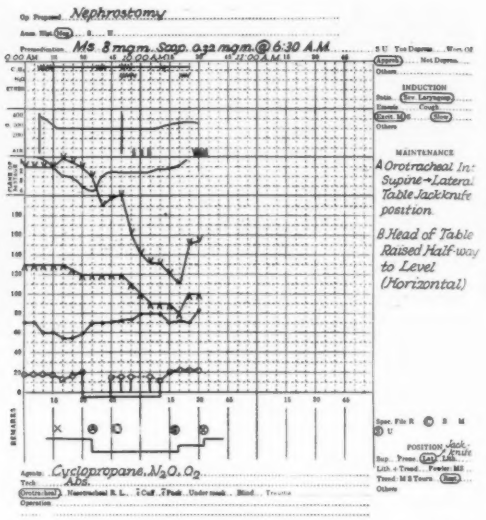
Op. Proposed Nephrostomy
Ms 8 mgm. Scop. 0.32 mgm. @ 6:30 A.M.
INDUCTION
MAINTENANCE
A Orotracheal Int: Supine → Lateral Table Jackknife position.
B Head of Table Raised Half-way to Level (Horizontal)
Agents Cyclopropane, N2O, O2
Abs.

Fig. 6. Circulatory and respiratory distress from kidney position for nephrectomy. Case No. 1745.

ture (6) favors relaxation of the abdominal muscles and may well be chosen for most abdominal operations.

The lateral kidney position is demonstrated in Figure 5. Intercostal breathing is interfered with on the dependent side by pressure on the thorax and on the upper side by increased tension on the lumbar and intercostal muscles. Venous return to the heart from all the extremities is retarded by gravity. Trauma due to this position and to surgical manipulation is transmitted to the splanchnic nerves and related plexuses causing an autonomic imbalance. Figure 6 presents the record of an individual, aged 50, physical status 3, who did not compensate satisfactorily for the harmful effects of being placed in this position. When head of table was raised toward the horizontal level an immediate rise in systolic, diastolic and pulse pressures occurred and supplementary breathing was no longer necessary.

Figure 7 is the anesthesia record of a 27 year old patient with a physical status of 1. She was placed in the lateral acute kidney position in order to secure maximum exposure for a nephrolithotomy. Her previous respiratory rate during anesthesia of 20 apparently normal breaths per minute changed to

Fig. 8. Extreme lithotomy with thighs flat on abdomen.

apnea as soon as the patient was laterally flexed. After 5 minutes of passive respiration, spontaneous breathing returned at a rate of 14. Fast shallow respiration persisted for the next 30 minutes until the table was raised to the horizontal position. The respiratory rate slowed to 24 and remained thus with good exchange for the duration of the surgical procedure. It was believed that the distress in this case was primarily due to pressure interference with respiratory movements. Nervous factors due to unusual stress in the splanchnic areas and circulatory embarrassment undoubtedly contributed to the condition.

Our suggestions relative to the lateral jackknife or kidney position are: (a) avoid extreme flexion of the patient on the table whenever possible; (b) confine the use of braces or kidney rest to the crest of the ilium and do not allow pressure against the ribs on the dependent side; (c) avoid the deeper planes of anesthesia; (d) employ supplemental breathing to avoid hypoxia if the exchange is poor.

The lithotomy position with extreme flexion of the thighs plus Trendelenburg (Fig. 8) is poorly tolerated by the obese patient due to the respiratory impairment resulting from the increased intra-abdominal pressure. Figure 9 shows the record of a 239 pound hypertensive female, aged 43, when placed in the lithotomy position for a brief gynecological operation. Respiratory distress was marked throughout.

When the legs are lowered following the completion of the perineal portion of a perineoabdominal resection of the rectum, circulatory embarrassment may occur due to the

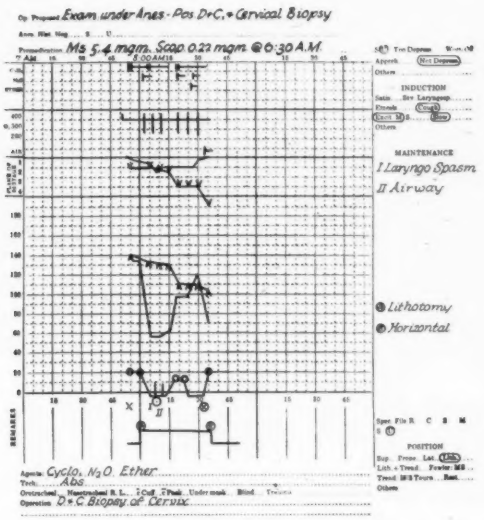


Fig. 9. Cardiovascular and respiratory changes of an obese patient in the lithotomy position. Case No. 688.

disparity between the increased functional volume of the vascular bed and the volume of circulating blood. Figure 10 shows a marked drop in blood pressure and pulse pressure occasioned by this change of position.

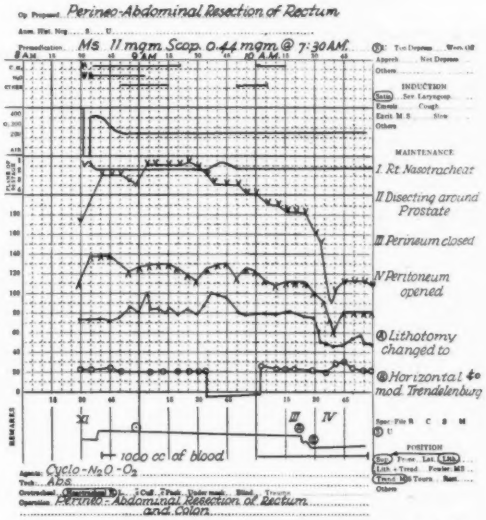


Fig. 10. Circulatory distress occasioned by abruptly changing from the lithotomy to the horizontal position. Case No. 2771.

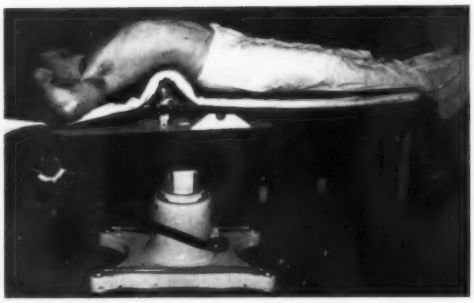

Fig. 11. Gall-bladder position with high elevation of the rest.

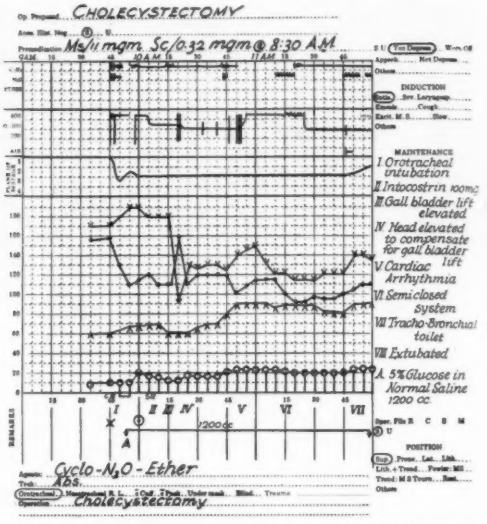


Fig. 12. Cardiovascular changes associated with elevation of gall-bladder lift. Case No. 1862.

The high "gall bladder" rest used with the cholecystectomy position (Fig. 10) necessitates profound anesthesia in order to relax the tension of the stretched abdominal muscles. In dogs we have noted an interference with the venous return from the kidneys and lower extremities due to partial collapse of the inferior vena cava as it is stretched against the hyperextended vertebral column. A similar condition with patients in the extreme gall bladder position appears to be possible. Figure 12 illustrates a circulatory response to the elevation of the gall-bladder rest.

Vigorous retraction on the lower ribs plus the trauma occasioned by the relaxation of the back muscles while the rest acts as a fulcrum against the suspended back probably cause as much discomfort and hesitancy to breathe deeply after the operation as does the pain from the actual site of the surgical procedure.

A folded sheet under the lower ribs plus good abdominal relaxation affords sufficient exposure so that this rest is never needed for upper abdominal surgery in our hospital. Block of the anterior divisions of the lower intercostal nerves facilitates abdominal muscle relaxation and allows the maintenance of light surgical anesthesia with good respiratory exchange. A further advantage of an intercostal block is that patients can breathe deeply in the immediate postoperative period without pain. With the use of the opiates thus reduced, respiratory depression and atelectasis are minimized.

The prone horizontal position (Fig. 13) is tolerated satisfactorily by patients of average build; however, the individual with a protruberant abdomen and poor abdominal muscle tone soon shows signs of distress. If an obese individual lies flat on the table, the intra-abdominal pressure will interfere with diaphragmatic action. If the pelvis is elevated with blocks so that the abdomen with weak muscular support swings free the systemic blood pressure often drops abruptly. In some such instances the pulse and pressure have not been detectable until the blocks have been removed and the patient turned back to the supine position. This circulatory failure occurs most frequently when a deeply anesthetized patient is suddenly turned from the supine to the prone position or when the visceral vessels have poor sympathetic tonus such as accompanies the second stage of thoracolumbar sympathectomy. The effective factor appears to be the pooling of blood in the visceral vessels due to inhibited splanchnic tonus and the uphill drainage from these dependent vessels into the overhanging inferior vena cava.

The record shown in Figure 14 is that of an obese female, aged 43, scheduled for the second stage of a bilateral thoracolumbar sympathectomy. The patient was given identical dosages of premedication and avertin for basal

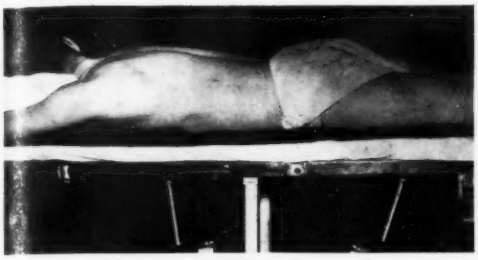

Fig. 13. Flat prone position without the advantages of properly placed blocks.

narcosis as she had received for the first stage procedure which was well tolerated. The induction with cyclopropane was uneventful. The patient was turned to the prone position and a pelvic rest elevated until the abdominal wall swung clear of the table. Within 5 minutes the respiration ceased, the pulse and the blood pressure were not obtainable. The operation was postponed. Two days later the patient was again prepared for the surgical procedure but the premedication was less than on the previous occasions and the avertin was omitted. Cyclopropane was used for the anesthetic and the pelvic elevator was not raised. The course of the operation was uneventful. We have learned to respect the decreased tolerance of the patient in the prone position after the splanchnic nerves have been sectioned or depressed.

The sitting position affords the least interference with costal respiration. An abdominal binder is recommended for patients with visceroptosis or relaxed abdominal musculature as these conditions inhibit the excursion of the diaphragm by permitting the viscera to exert an increased downward pull. Since the breathing then is largely costal, deep surgical anesthesia must be avoided. A further contraindication to the use of profound anesthesia is the tendency of the blood to accumulate in the lower extremities and visceral area. The application of elastic bandages to the feet and legs while the patient is still in the supine position is desirable.

In the sitting position even short periods of anoxia resulting from low arterial pressure may damage the cerebral cortex. For this reason, personality changes following neuro-

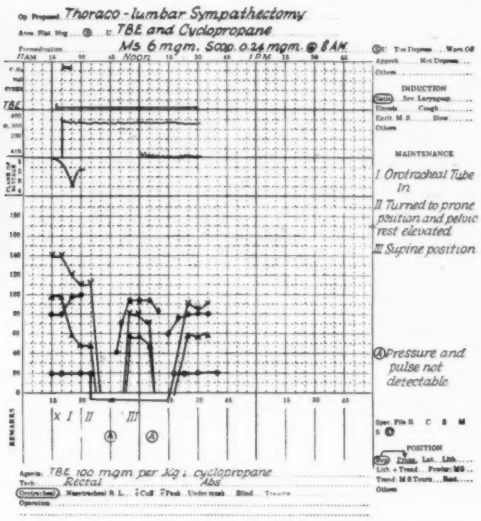


Fig. 14. Vascular collapse and respiratory failure occasioned by a rapid change from the supine to the prone position and high elevation of the pelvic rest. Case No. 2703.

surgical procedures should not always be attributed to the trauma and edema coincident with the operation.

## SUMMARY

The supine horizontal position is the one best tolerated by the anesthetized patient. Circulatory embarrassment due to the increased effects of gravity upon venous return are directly proportional to the variation from the horizontal plane. Other causes of circulatory embarrassment are: (a) loss of muscle tone; (b) loss of autonomic tone; (c) abnormal intrathoracic pressure; (d) respiratory depression; (e) abnormal intra-abdominal pressure; (f) systemic disease. Respiratory embarrassment occurs with depression of nervous control whether central or peripheral and with mechanical interference with respiratory excursion. With extreme positions of Trendelenburg or lithotomy, the increased abdominal pressure upon the diaphragm may markedly inhibit its activity, while lateral or prone positions with improperly placed blocks and pressure interfere with intercostal excursions.

Adequate respiratory exchange should be maintained, thereby avoiding the muscle tension accompanying hypoxia. If the anesthetist

produces the degree of relaxation afforded by the anesthetic drugs available, he will find that the surgeon will usually co-operate and not demand extreme variations of position from the horizontal for patients with poor reserve. If respiratory and circulatory depression can be forestalled by avoiding the extremes of position, more time may safely be used for the surgical procedure. The patient also will benefit by experiencing a less stormy postoperative course.

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# THE EFFECT OF MECHANICAL ARTIFICIAL RESPIRATION UPON MAINTENANCE OF THE CIRCULATION

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THE two principal functions of resuscitation are oxygenation of the blood and the circulation of this oxygenated blood to the vital centers. Oxygenation of the blood takes place through pulmonary ventilation. Pulmonary ventilation has long been considered to be the sole requisite of resuscitation and, indeed, up to the time of circulatory cessation, adequate pulmonary ventilation may be all that is necessary for resuscitation to be successful. Once the circulation has stopped, however, the situation is drastically changed and pulmonary ventilation alone cannot be expected to bring about a successful resuscitation. The oxygenated blood in the lungs is of little or no value unless it can be transported to the vital centers and distributed over the body.

This brings us up to the second function of resuscitation, namely, the transportation and distribution of the oxygenated blood to the cells of the cardiac and central nervous systems. In past experimental work (2) we gained the clinical impression that the inflation and deflation of the lungs had a very definite effect upon the movement of the blood column, in addition to and beyond the effect of the active heart beat.

Not until recently has it been possible to demonstrate whether or not a given resuscitation procedure could produce any actual movement of the blood itself. The purpose of this paper is to describe a method for determining the effect of various resuscitative procedures upon the circulation. Essentially the method consists in the introduction of a tracer substance into the blood stream of an animal immediately following death by asphyxiation and recording any movement of this substance during the application of a resuscitative procedure. The tracers which have been used are radioactive sodium, which we have previously reported (3), fluorescein and oxygen. This report concerns the use of oxygen only.

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While pulmonary ventilation has received most of the emphasis in the investigative work of modern authors, it remained for the Russians to attack this problem of resuscitation from the viewpoint of circulation rather than ventilation. Negovski and his co-workers have demonstrated in dramatic fashion the value of circulatory movement by the intravascular injections of oxygenated blood and glucose under positive pressures. While these authors emphasize the transportation or circulation of oxygenated blood, nevertheless they call attention to the absolute necessity of adequate pulmonary ventilation being provided at the same time.

The degree and efficiency of pulmonary ventilation varies in each method of resuscitation. All methods produce ventilation by one of three ways: (1) inflation of the lungs and return to the starting point; (2) deflation of the lungs and return to the starting point; (3) a combination of inflation alternating with deflation of the lungs.

The manual methods are inefficient, inconstant, and uncontrollable. The mechanical methods are more efficient and are controlled by a constant volume or pressure. Only those resuscitating apparatuses employing a controlled pressure can be safely used.

The use of oxygen as a tracer substance differs from the intravascular injection of other tracers in that oxygen is not injected but is brought into contact with the blood in the pulmonary capillaries by means of a closed ventilating system. In a condition of anoxia, a stream of oxygen directed into the terminal air sacs of the lung will come into contact with the red blood cells. These cells take up the oxygen and are then transported over the

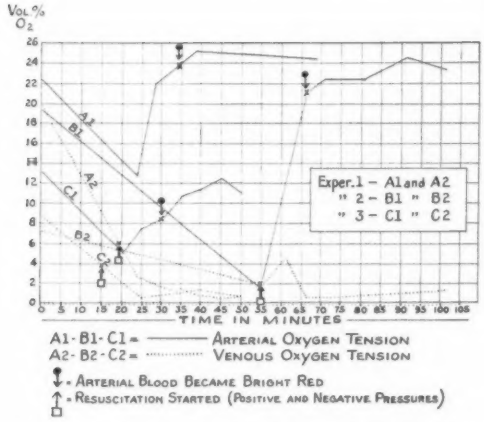
VOL. % O2
TIME IN MINUTES
Exper. 1 – A1 and A2
" 2 – B1 " B2
" 3 – C1 " C2
A1-B1-C1 = ARTERIAL OXYGEN TENSION
A2-B2-C2 = VENOUS OXYGEN TENSION
= ARTERIAL BLOOD BECAME BRIGHT RED
= RESUSCITATION STARTED (POSITIVE AND NEGATIVE PRESSURES)

Fig. 1. Alternating positive and negative pressures with 100 per cent oxygen used on 3 dogs. The vertical line shows the blood oxygen tension in volume per cent. The horizontal line indicates the time in minutes.

Experiment 1. The arterial blood oxygen tension has regained its preasphyxia level in approximately 10 minutes after resuscitation was started.

Experiment 2. The arterial blood oxygen tension rose rapidly and has passed its preasphyxia level in 11 minutes after resuscitation was started.

Experiment 3. There was a rapid rise of the arterial blood oxygen tension in the first 10 minutes of resuscitation followed by a more gradual rise. The blood became bright red in 15 minutes.

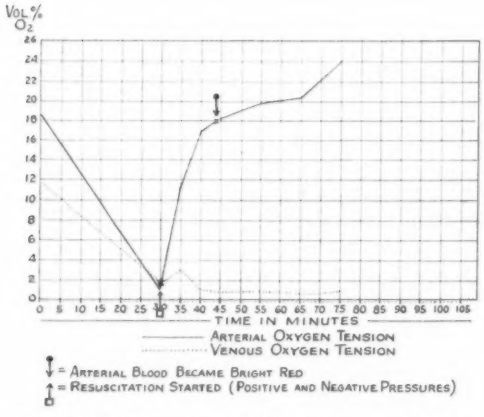
VOL. % O2
TIME IN MINUTES
ARTERIAL OXYGEN TENSION
VENOUS OXYGEN TENSION
= ARTERIAL BLOOD BECAME BRIGHT RED
= RESUSCITATION STARTED (POSITIVE AND NEGATIVE PRESSURES)

Fig. 2. This is a composite of the 3 experiments in Figure 1. The oxygen tension of the arterial blood rose rapidly in the first 15 minutes of resuscitation, continued to rise and at 45 minutes was much higher than the preasphyxia level. The arterial blood became bright red in 14 minutes. This charted curve is superior to those shown in Figures 4 and 6 and indicates a more efficient movement (volume and speed) of the blood column by this method.

TABLE I.—VENOUS AND ARTERIAL BLOOD OXYGEN TENSION WITH ALTERNATING POSITIVE AND NEGATIVE PRESSURE RESUSCITATOR USING 100 PER CENT OXYGEN

| Dog 1 | | | Dog 2 | | |
|---|---|---|---|---|---|
| Time of collection of blood | Volume per cent oxygen | | Time of collection of blood | Volume per cent oxygen | |
| | Venous | Arterial | | Venous | Arterial |
| Prior to asphyxiation | 19.07 | 22.24 | Prior to asphyxiation | 7.23 | 19.41 |
| 5 minutes after resuscitation started | 2.64 | 12.59 | Following asphyxiation | 1.87 | 1.28 |
| 10 minutes after resuscitation started | 1.8 | 21.98 | 6 minutes after resuscitation started | 4.53 | 15.84 |
| 15 minutes after resuscitation started | 1.08 | 23.76* | 11 minutes after resuscitation started | 0.66 | 21.09* |
| 20 minutes after resuscitation started | 1.11 | 25.73 | 16 minutes after resuscitation started | 0.56 | 22.36 |
| 30 minutes after resuscitation started | 0.72 | 25.02 | 26 minutes after resuscitation started | 0.74 | 22.43 |
| 50 minutes after resuscitation started | | 24.39 | 36 minutes after resuscitation started | 0.75 | 24.5 |
| | | | 46 minutes after resuscitation started | 0.92 | 23.5 |

| Dog 3 | | | Average of experiments 1, 2, and 3 | | |
|---|---|---|---|---|---|
| Prior to asphyxiation | 8.66 | 12.91 | Prior to asphyxiation | 11.86 | 18.19 |
| 5 minutes after resuscitation started | 1.48 | 4.84 | Following asphyxiation | 1.87 | 1.28 |
| 10 minutes after resuscitation started | 0.24 | 7.53 | 5 minutes after resuscitation started | 2.88 | 11.09 |
| 15 minutes after resuscitation started | 0.66 | 8.24* | 10 minutes after resuscitation started | 0.9 | 16.87 |
| 20 minutes after resuscitation started | 1.08 | 10.55 | 15 minutes after resuscitation started | 0.77 | 18.12 |
| 25 minutes after resuscitation started | 0.66 | 11.5 | 25 minutes after resuscitation started | 0.84 | 19.79 |
| 30 minutes after resuscitation started | 0.42 | 12.29 | 35 minutes after resuscitation started | 0.67 | 20.14 |
| 35 minutes after resuscitation started | 0.52 | 10.9 | 45 minutes after resuscitation started | 0.92 | 23.95 |

*Arterial blood became bright red.

vascular network of the body by means of the circulatory movement. When circulatory movement no longer exists, the stream of oxygen directed into the terminal air sacs cannot now relieve the anoxia, for the oxygenated

TABLE II.—VENOUS AND ARTERIAL BLOOD OXYGEN TENSION WITH NEGATIVE PRESSURE RESUSCITATOR USING 60 PER CENT OXYGEN

| Dog 4 | | | Dog 5 | | |
|---|---|---|---|---|---|
| Time of collection of blood | Volume per cent oxygen | | Time of collection of blood | Volume per cent oxygen | |
| | Venous | Arterial | | Venous | Arterial |
| Prior to asphyxiation | 12.12 | 22.21 | Prior to asphyxiation | 8.7 | 20.8 |
| Following asphyxiation | 2.78 | 1.2 | Following asphyxiation | 2.63 | 1.24 |
| 5 minutes after resuscitation started | 1.84 | 0.45 | 5 minutes after resuscitation started | 1.36 | 1.05 |
| 10 minutes after resuscitation started | 0.81 | 0.52 | 10 minutes after resuscitation started | 1.44 | 2.93 |
| 15 minutes after resuscitation started | 1.00 | 2.48 | 15 minutes after resuscitation started | 0.92 | 12.36 |
| 20 minutes after resuscitation started | 0.72 | 11.07 | 20 minutes after resuscitation started | 1.1 | 21.45* |
| 35 minutes after resuscitation started | 0.85 | 20.14* | 30 minutes after resuscitation started | 0.91 | 20.76 |
| 50 minutes after resuscitation started | 0.01 | 22.95 | 40 minutes after resuscitation started | 0.79 | 18.67 |
| | 1 | | 60 minutes after resuscitation started | | 21.82 |

| Dog 6 | | | Average of experiments 4, 5, and 6 | | |
|---|---|---|---|---|---|
| Prior to asphyxiation | 8.33 | 16.85 | Prior to asphyxiation | 9.72 | 19.95 |
| Following asphyxiation | 1.74 | 1.42 | Following asphyxiation | 2.38 | 1.29 |
| 5 minutes after resuscitation started | 0.89 | 0.73 | 5 minutes after resuscitation started | 1.36 | 0.74 |
| 10 minutes after resuscitation started | 1.01 | 2.02 | 10 minutes after resuscitation started | 1.08 | 1.82 |
| 15 minutes after resuscitation started | 1.24 | 8.90* | 15 minutes after resuscitation started | 1.05 | 7.94 |
| 20 minutes after resuscitation started | 0.85 | 11.16 | 20 minutes after resuscitation started | 0.89 | 14.56 |
| 30 minutes after resuscitation started | 0.71 | 11.63 | 30 minutes after resuscitation started | 0.85 | 14.14 |
| 45 minutes after resuscitation started | 0.85 | 12.81 | 45 minutes after resuscitation started | 0.43 | 19.19 |

*Blood (arterial) became bright red.

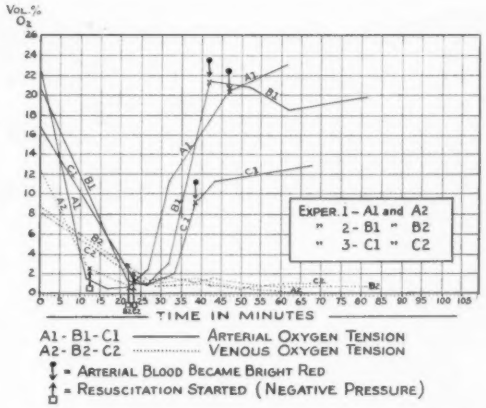
VOL. % O2
TIME IN MINUTES
EXPER. 1 – A1 and A2
" 2 – B1 " B2
" 3 – C1 " C2
A1 - B1 - C1 ——— ARTERIAL OXYGEN TENSION
A2 - B2 - C2 ..... VENOUS OXYGEN TENSION
= ARTERIAL BLOOD BECAME BRIGHT RED
= RESUSCITATION STARTED (NEGATIVE PRESSURE)

Fig. 3. Negative pressures and release with 60 per cent oxygen was used in 3 experiments.

Experiment 1. The arterial blood oxygen tension was lowered at first and later began to climb. It gained its preasphyxia level in approximately 50 minutes after resuscitation was started.

Experiment 2. The arterial blood oxygen tension reached its preasphyxia level in approximately 20 minutes after resuscitation was started.

Experiment 3. The arterial blood oxygen tension did not reach its preasphyxia level in 45 minutes, although the blood became bright red in 9 minutes.

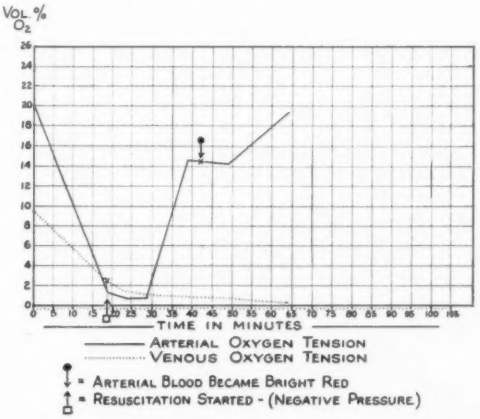
VOL. % O2
TIME IN MINUTES
——— ARTERIAL OXYGEN TENSION
..... VENOUS OXYGEN TENSION
= ARTERIAL BLOOD BECAME BRIGHT RED
= RESUSCITATION STARTED - (NEGATIVE PRESSURE)

Fig. 4. This is a composite of the 3 experiments in Fig. 3. The arterial blood oxygen tension fell at first and later rose but required approximately 45 minutes to regain the preasphyxia level. This curve is inferior to that of Figure 2 where positive and negative pressures were used.

cells remain in the pulmonary capillaries where they are of no value.

The mechanical inflation and deflation of the lungs produces a regular dilatation and compression of the pulmonary capillaries which results in a movement of the blood contained in these capillaries. Since the valves of the heart and veins prevent a back flow, any movement of the circulation must be in one

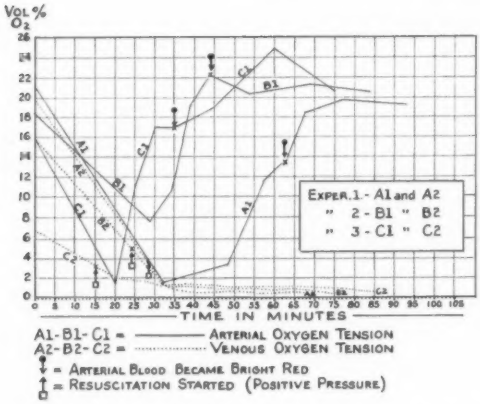
VOL. % O2
EXPER. 1 - A1 and A2
" 2 - B1 " B2
" 3 - C1 " C2
TIME IN MINUTES
A1-B1-C1 = ARTERIAL OXYGEN TENSION
A2-B2-C2 = VENOUS OXYGEN TENSION
= ARTERIAL BLOOD BECAME BRIGHT RED
= RESUSCITATION STARTED (POSITIVE PRESSURE)

Fig. 5. Positive pressures and release with 100 per cent oxygen was used in 3 experiments.

Experiment 1. The arterial oxygen tension did not reach its preasphyxia level in 65 minutes. The blood became bright red in 35 minutes.

Experiment 2. The arterial blood oxygen tension reached the preasphyxia level in about 20 minutes.

Experiment 3. The arterial blood oxygen tension rose rapidly and reached the preasphyxia level in approximately 15 minutes.

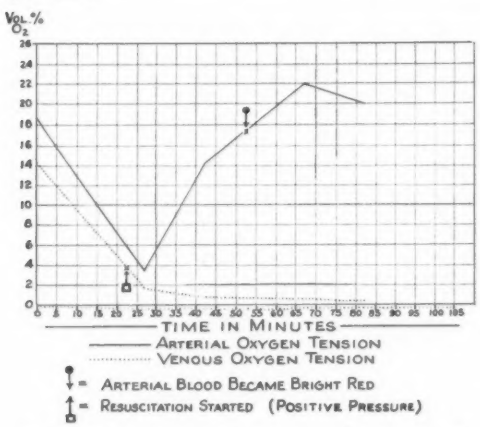


Fig. 6. This is a composite of the 3 experiments in Fig. 5. The arterial blood oxygen tension rose rapidly in the first 20 minutes of resuscitation. This curve is inferior to that of Figure 2 where positive and negative pressures were used.

direction and if of sufficient magnitude would complete the circuit from the lungs to the left heart, to the arteries to veins to right heart and back to lungs again. When the heart is no longer beating, the mechanical movement of the blood column (by any means) in any section of the body may produce a corresponding movement of the blood column ahead of and behind that section where the movement was initiated.

TABLE III.—VENOUS AND ARTERIAL BLOOD OXYGEN TENSION WITH POSITIVE PRESSURE RESUSCITATOR USING 100 PER CENT OXYGEN

| Dog 7 | | | Dog 8 | | |
|---|---|---|---|---|---|
| Time of collection of blood | Volume per cent oxygen | | Time of collection of blood | Volume per cent oxygen | |
| | Venous | Arterial | | Venous | Arterial |
| Prior to asphyxiation | 19.91 | 21.43 | Prior to asphyxiation | 15.87 | 18.48 |
| 5 minutes after resuscitation started | 1.2 | 1.57 | 5 minutes after resuscitation started | 3.06 | 7.6 |
| 20 minutes after resuscitation started | 0.66 | 3.25 | 10 minutes after resuscitation started | 1.21 | 10.43 |
| 30 minutes after resuscitation started | 0.42 | 11.65 | 15 minutes after resuscitation started | 0.68 | 19.18 |
| 35 minutes after resuscitation started | 0.49 | 13.53* | 20 minutes after resuscitation started | 0.54 | 22.14* |
| 40 minutes after resuscitation started | 0.44 | 18.34 | 30 minutes after resuscitation started | 0.71 | 20.31 |
| 50 minutes after resuscitation started | — | 19.58 | 45 minutes after resuscitation started | 0.81 | 21.44 |
| 65 minutes after resuscitation started | — | 19.06 | 60 minutes after resuscitation started | 0.5 | 20.13 |

| Dog 9 | | | Average of experiments 7, 8, and 9 | | |
|---|---|---|---|---|---|
| Prior to asphyxiation | 6.61 | 15.73 | Prior to asphyxiation | 14.13 | 18.55 |
| 5 minutes after resuscitation started | 2.00 | 1.38 | 5 minutes after resuscitation started | 1.73 | 3.53 |
| 10 minutes after resuscitation started | 1.72 | 11.14 | 20 minutes after resuscitation started | 0.81 | 14.05 |
| 15 minutes after resuscitation started | 1.29 | 16.8 | 30 minutes after resuscitation started | 0.63 | 17.01 |
| 20 minutes after resuscitation started | 1.24 | 16.76* | 45 minutes after resuscitation started | 0.65 | 21.96 |
| 30 minutes after resuscitation started | 0.76 | 19.06 | 60 minutes after resuscitation started | 0.47 | 19.95 |
| 45 minutes after resuscitation started | 0.71 | 24.87 | The arterial blood became bright red in 30 minutes. | | |
| 60 minutes after resuscitation started | 0.44 | 20.06 | | | |

*Arterial blood became bright red.

We have been able to demonstrate that the situation described does take place and that the mechanical inflation and deflation of the lungs does produce a movement of the blood column and in this manner the blood can be circulated over the entire body.

### TECHNICAL PROCEDURE

All of the experimental procedures were done on dogs. The animal was anesthetized with intraperitoneal nembutal. One femoral artery and one femoral vein was cannulized and the cannula left in site. An endotracheal tube with occlusion cuff was then inserted and the cuff inflated to make a leak-proof and closed connection with the lungs. A sample of blood was collected from one of the femoral arteries and femoral veins for determination of its oxygen saturation or tension. The specimens were collected under oil and the oxygen tension was determined by the Van-Slyke manometric method. This first specimen was labeled as "preasphyxia," and was used for comparison. To prevent the intravascular clotting of the blood which occurs soon after death, 2 to 5 cubic centimeters of heparin was injected intravenously. Five to 10 minutes after the heparin was injected the endotracheal tube was clamped off, and the animal was allowed to succumb by obstructive asphyxia. Clinical death took place in about 8 to 10 minutes. In order to insure complete (biological) death with no subsequent cardiac activity, the tube remained clamped for an additional 20 to 30 minutes. At the end of this time a second specimen of blood was collected from the femoral artery and vein for analysis of the oxygen tension and this was labeled "postasphyxia." The endotracheal tube was now unclamped and connected to a resuscitator. A resuscitative procedure was begun and continued for 45 to 60 minutes. At approximately 5 minute intervals, additional specimens of blood were taken from the femoral artery and vein for analysis of the oxygen tension.

This method of frequent analysis of the blood in the femoral vessels made it possible to determine any change in the oxygen tension while the lungs were being mechanically inflated and deflated with oxygen. If this inflation and deflation of the lungs produces a forwarding movement of the oxygenated blood cells in the pulmonary capillaries, there would be a gradual increase in the oxygen tension of the blood in the femoral vessels since the blood in the pulmonary capillaries is now thoroughly oxygenated. A total of 15 experiments were done. Alternating positive and negative pressures were used in 5 experiments positive pressure and release was used 4 times and negative pressure (suction and release) was used 6 times. From each group 3 typical experiments were charted.

The resuscitators delivered a positive pressure of 14 millimeters of mercury and a negative pressure of minus 9 millimeters of mercury. A separate resuscitator was used for the positive pressure and the negative pressure and the alternating positive and negative pressures. The resuscitators for the alternating pressures and for the positive pressure delivered 100 per cent oxygen. The resuscitator for the negative pressure used a mixture of equal parts of atmospheric air and 100 per cent oxygen. This would make the oxygen content of the gas delivered by the negative pressure resuscitator only 60 per cent. The rate of the inflation and deflation of the lungs was approximately 20 per minute.

### DISCUSSION

The only place where blood cells can become oxygenated is in the pulmonary capillaries and the only way these oxygenated cells can be transported is through the vascular system. The gradual appearance and increase, after asphyxia, of oxygenated cells in the femoral artery constitutes definite proof of the forwarding movement of the blood from the pulmonary capillaries to the femoral artery. As the heart is no longer beating or active, this forwarding movement of the blood is produced by the mechanical inflation and deflation of the lungs. Therefore, in mechanical artificial respiration we have a method of producing pulmonary ventilation as well as circulation of the blood.

The type of resuscitation seems to make a considerable difference in the pulmonary ventilation and also in the speed of the circulation. A study of the tables and charts shows that

when alternating positive and negative pressures are used the oxygen tension of the blood in the femoral artery regains its preasphyxia level in approximately 17 minutes and the blood as it is withdrawn from the femoral artery changed in color from a dark blue (black) to a bright red color in approximately 14 minutes. This visual color test varies from time to time and is subject to criticism because of its lack of complete accuracy; however, we believe it does have some value.

When the positive pressure resuscitator was used the oxygen tension of the blood in the femoral artery regained its preasphyxia level in approximately 31 minutes, and the blood was visibly bright red in approximately 25 minutes. Both of these times are considerably longer than when alternating positive and negative pressure resuscitation was used.

When the negative pressure resuscitator was used the oxygen tension of the blood in the femoral artery regained its preasphyxia level in approximately 35 minutes, and the blood became visibly bright red in 23 minutes. This also is longer than the results obtained when the alternating pressure resuscitator was used. There is little difference in the comparison of the results obtained by the use of the positive pressure resuscitator and the negative pressure, although the latter machine delivered only 60 per cent of oxygen; therefore these figures would be subject to an upward revision if 100 per cent oxygen had been delivered. Both are inferior to the alternating pressure resuscitator.

It will be noted that the oxygen tension of the blood in the femoral vein in no instance regained its preasphyxia level and on the contrary, the longer the resuscitation, the lower the oxygen tension of the venous blood. The only explanation we can offer for this is that the blood column was moving so slowly that in the passage through the tissue capillaries the oxygen was more or less completely removed and utilized by the anoxic tissues.

The movement of the blood column by the mechanical inflation and deflation of the lungs is in no way comparable to the volume or speed of the normal circulation. However, the fact that such movement of the blood can be produced seems to be of definite clinical importance.

In a previous report (3) we called attention to the value of heparin in resuscitation. This prevents clotting and keeps the blood in a fluid state. As a result the blood can be more effectively circulated and this increases the possible survival time. Once the blood is clotted there is no possibility of any further circulatory movement.

## CONCLUSIONS

We have described a method for determining the effect of mechanical artificial respiration upon the circulation when the heart is no longer beating. This is done by the introduction of tracer substances into the vascular system of animals immediately after death, and observing the movement of these tracers while the lungs are inflated and deflated. The tracer which was used in this series of experiments was oxygen.

By this method we have shown that the mechanical inflation and deflation of the lungs produces an actual movement of the blood column and that the blood can be circulated over the entire body without the benefit of any heart action whatever.

Mention is again made of the value of heparin in resuscitation.

Those mechanical resuscitators employing positive and negative pressures were more efficient in circulating the blood than were those employing only positive pressure and release or negative pressure and release.

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# A STUDY OF PROTEIN HYDROLYSATES, OSSEIN GELATIN AND GLUCOSE IN PARENTERAL NUTRITION

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IN the belief that the maintenance of nitrogen equilibrium would reduce the period required for convalescence in surgical patients, an intensive study of a number of available products for parenteral nutrition was undertaken. The usefulness of parenteral feeding is confined to those patients in whom oral feeding cannot be accomplished safely. Such patients are usually those with lesions of the gastrointestinal tract, as peptic ulcer or neoplasm in esophagus, stomach, or intestine.

We were concerned on the one hand with the effectiveness of the various feeding programs in producing a positive nitrogen balance and on the other hand with the various practical difficulties, such as thrombosis, pyrexia, or nausea, which tend to interfere with the success of the method.

Among the objectives of the study were the following: (1) to determine what the nitrogen and caloric requirements for equilibrium would be after major operations; (2) to determine whether they would be substantially different from the amounts required enterally; (3) to determine whether there were any striking differences in the response of patients to the different preparations of hydrolyzed protein tested; (4) to determine the value of ossein gelatin as a constituent of a nutritive mixture for intravenous administration.

Inasmuch as the studies were carried out in patients, there were too many uncontrolled variables to permit the detection of small differences.

## METHODS

The collection of specimens and the analytical methods were the same as those reported in an earlier paper (6). The intravenous infusions were given continuously when possible, and it was seldom that any patient received his infusion less than 22 hours per day. Thus the rate of infusion could be reduced to about 125 cubic centimeters per hour. In every instance the administration was carried out by a closed system, and, in general, the infusion was not allowed to run into the same vein for more than 24 hours. The period of study was 5 days beginning within 24 hours after operation unless otherwise indicated.

The preparations used were as follows:

1. Parenamine (15 per cent solution), an acid hydrolysate of casein fortified by the addition of tryptophane.

2. Amigen (5 per cent with 5 per cent glucose), an enzymatic hydrolysate of casein and pork pancreas.

3. A similar hydrolysate, from which certain substances had been removed by extraction with acetone, sent to us in powder form by Doctor Olaf Rask of Johns Hopkins School of Public Health and made up by us in sterile solution of the desired concentration.

4. Casein aminosol (5 per cent with 5 per cent glucose) enzymatic hydrolysate of casein and pancreas.

5. Fibrin aminosol (5 per cent with 5 per cent glucose) an enzymatic hydrolysate of fibrin.

6. Gelatin, Knox P-20, 6 per cent.

A volume of one or more of these solutions containing sufficient nitrogen to give the patient 0.3 gram of nitrogen per kilogram daily was used as the starting point for the feeding mixture.

An average figure of several analyses was used to calculate nitrogen content of each of the various preparations.

Sufficient amounts of sterile 50 per cent solution of glucose were added to give a caloric intake of 30 calories per kilogram daily, and

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the total daily volume was made up to 3,000 cubic centimeters. The salt content was varied in accordance with the needs of the patient, and additional fluid was given when necessary to compensate for abnormal losses.

The gelatin appearing unchanged in the urine during the period of the infusion was determined and included in the total nitrogen loss. Also the gelatin nitrogen occurring in the urine during the 3 days after the infusion ended was added to the total nitrogen excretion for the period of infusion. The excretion of gelatin after this 3 day period was so small that it could not be determined accurately by the method used (5, 6).

## RESULTS

The metabolic data obtained are presented in Table I. A nitrogen balance of $\pm 1.0$ gram per day was considered as equilibrium, and figures outside of this range were classified as positive or negative as the case might be. The first 22 patients were fresh postoperative cases. The last 4 were nonoperative patients or were studied before operation.

Three patients who received gelatin as the sole source of nitrogen in amounts ranging from 0.25 to 0.29 gram of nitrogen per kilogram per day remained in negative nitrogen balance. Only 1 of them, however, received a reasonably good caloric intake (28 calories per kilogram per day). It was to be expected that this incomplete protein would fail to produce nitrogen equilibrium. In fact, larger negative nitrogen balances had been expected, and the results suggested the possibility of partial utilization during the 5 day trials.

Twelve patients received 4 preparations of hydrolyzed protein. Eight of these received from 0.26 to 0.31 gram of nitrogen per kilogram per day. One was in equilibrium, and 7 were in negative nitrogen balance. One additional patient who received only 0.20 gram of nitrogen per kilogram per day was in equilibrium. In 3 instances the nitrogen intake was increased to 0.54, 0.62, and 0.69 gram of nitrogen per kilogram per day respectively, and all were in strongly positive nitrogen balance.

Seven patients received half the nitrogen intake in the form of gelatin and half in the form of hydrolyzed protein. Five of these received 0.30 gram of nitrogen per kilogram per day or less, and in this group 3 were negative and 2 were in equilibrium. One of the 3 who was negative had a very deficient caloric intake. The other 2 patients in this group received 0.40 and 0.47 gram of nitrogen per kilogram per day, and both were strongly positive although their caloric intakes were low. In view of the fact that gelatin is deficient in certain of the essential amino acids, it is surprising that the substitution of this material for one-half of the protein hydrolysate was followed by comparable results.

Finally 4 nonoperative patients were studied. Nitrogen intake ranged from 0.30 to 0.49 gram per kilogram per day. All were in positive nitrogen balance in spite of the fact that 2 of them had relatively low caloric intakes.

## UNTOWARD REACTIONS

Apart from hyperpyrexia two types of reactions were encountered with the intravenous administration of protein hydrolysates, a systemic reaction and phlebitis. The systemic reaction was usually associated with rapid administration of one of the hydrolysates. It consisted of a sensation of flushing over the neck and face accompanied by a sense of constriction about the nose, upper lip, and temples. Nausea and vomiting sometimes followed if the infusion was continued at a rapid rate. A number of patients, in addition to those having nitrogen balance studies, were tested for the systemic reaction with various hydrolysates. The addition of 1 per cent or more of gelatin protein usually prevented the systemic reaction.

Thrombophlebitis occurred with considerable regularity in the vein employed for the infusion after a number of hours of continuous administration. It sometimes involved tributary veins as well. It was not influenced by the addition of gelatin nor were any of the preparations of hydrolyzed protein free from the tendency to produce it. The use of a plastic tube instead of a needle considerably delayed the onset of thrombosis.

The problem of thrombophlebitis is a serious one because patients who need the benefit of parenteral protein are frequently those who will also need their veins for other infusions

TABLE I.—METABOLIC DATA

| Patient | Infusion | Intake | | | | | Output | | | | | Balance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total nitrogen | Nitrogen /kgm. /day | Hydrolysate nitrogen /kgm. /day | Gelatin nitrogen /kgm. /day | Calories /kgm. /day | Total nitrogen | Urine nitrogen | Gelatin nitrogen | Drainage nitrogen | Feces nitrogen | Total | Daily |
| | | grams | grams | grams | grams | | grams | grams | grams | grams | grams | grams | grams |
| **Gelatin** | | | | | | | | | | | | | |
| Ml. | Knox P20 6% | 94.7 | 0.25 | — | 0.25 | 7 | 136.7 | 88.1 | 37.1 | 0.5 | 5.0* | −42.0 | −8.4 |
| Ma. | Knox P20 6% | 86.0 | 0.28 | — | 0.28 | 28 | 110.9 | 58.1 | 14.4 | 3.4 | 5.0* | −24.9 | −4.9 |
| Ra. | Knox P20 6% | 72.7 | 0.29 | — | 0.29 | 8 | 79.6 | 53.7 | 18.8 | 2.1 | 5.0* | −6.9 | −1.3 |
| **Hydrolyzed protein** | | | | | | | | | | | | | |
| To. | Rask AA | 60.3 | 0.20 | 0.26 | — | 34 | 72.1 | 65.9 | — | 1.2 | 5.0* | −11.8 | −2.3 |
| Ki. | Rask AA | 86.7 | 0.28 | 0.28 | — | 39 | 108.1 | 99.6 | — | 3.5 | 5.0* | −21.4 | −4.2 |
| McL. | Amigen 5% | 90.0 | 0.30 | 0.30 | — | 19 | 117.4 | 101.5 | — | 10.9 | 5.0* | −27.4 | −5.4 |
| Du. | Amigen 5% | 103.8 | 0.30 | 0.30 | — | 30 | 133.6 | 124.7 | — | 3.9 | 5.0* | −29.8 | −5.9 |
| Ia. | Casein aminosol 5% | 77.9 | 0.27 | 0.27 | — | 31 | 89.8 | 83.8 | — | 1.0 | 5.0* | −11.9 | −2.3 |
| Ah. | Casein aminosol 5% | 97.0 | 0.30 | 0.30 | — | 36 | 98.1 | 84.4 | — | 8.7 | 5.0* | −1.1 | −0.2 |
| Go. | Fibrin aminosol 5% | 100.5 | 0.31 | 0.31 | — | 33 | 113.2 | 100.3 | — | 1.9 | 5.0* | −12.7 | −2.5 |
| Wh. | Amigen 5% | 64.2 | 0.20 | 0.20 | — | 31 | 64.9 | 58.1 | — | 1.8 | 5.0* | −0.7 | −0.1 |
| Ha. | Amigen 5% | 87.9 | 0.29 | 0.29 | — | 17 | 132.8 | 123.5 | — | 4.3 | 5.0* | −44.9 | −8.9 |
| Po. | Casein aminosol | 189.0 | 0.69 | 0.69 | — | 40 | 148.6 | 143.6 | — | — | 5.0* | +40.4 | +8.0 |
| Ca. | Fibrin aminosol | 140.5 | 0.62 | 0.62 | — | 38 | 119.1 | 113.2 | — | 0.9 | 5.0* | +21.4 | +4.2 |
| McC. | Fibrin aminosol | 130.5 | 0.54 | 0.54 | — | 39 | 105.1 | 98.1 | — | 2.0 | 5.0* | +25.4 | +5.0 |
| **Hydrolyzed protein +gelatin** | | | | | | | | | | | | | |
| Er. | Rask AA+Knox P20 | 83.7 | 0.23 | 0.18 | 0.05 | 6 | 144.6 | 122.2 | 15.8 | 1.0 | 5.0* | −60.9 | −12.1 |
| Mi. | Casein aminosol+Knox P20 | 86.0 | 0.29 | 0.14 | 0.15 | 29 | 98.0 | 67.9 | 19.6 | 5.5 | 5.0* | −12.0 | −2.4 |
| Ta. | Fibrin aminosol+Knox P20 | 72.0 | 0.30 | 0.15 | 0.15 | 34 | 74.6 | 53.4 | 15.0 | 1.2 | 5.0* | −2.6 | −0.5 |
| Fa. | Casein aminosol+Knox P20 | 73.0 | 0.30 | 0.15 | 0.15 | 34 | 73.7 | 50.6 | 14.4 | 3.7 | 5.0* | −0.7 | −0.1 |
| May | Fibrin aminosol+Knox P20 | 82.5 | 0.27 | 0.14 | 0.13 | 27 | 103.6 | 96.2‡ | | 2.4 | 5.0* | −21.1 | −4.2 |
| Th. | Rask AA+Knox P20 | 147.3 | 0.40 | 0.20 | 0.20 | 10 | 119.1 | 81.6 | 25.2 | 4.5 | 7.8 | +28.2 | +5.6 |
| Ry. | Rask AA+Knox P20 | 131.0 | 0.47 | 0.32 | 0.15 | 12 | 112.9 | 89.0 | 18.9 | — | 5.0* | +18.1 | +3.6 |
| **Unoperated** | | | | | | | | | | | | | |
| Mat. | Rask AA+Knox P20 | 64.6 | 0.30 | 0.24 | 0.06 | 19 | 47.3 | 35.8 | 4.0 | — | 7.5 | +17.3 | +3.4 |
| Ho. | Rask AA+Knox P20 | 123.0 | 0.49 | 0.36 | 0.13 | 43 | 73.7+ | 55.6 | 13.1⊕ | — | 5.0* | +49.3 | +9.8 |
| McK.** | Stearns AA+Knox P20+Hosp. | 110.8 | 0.45 | 0.29 | 0.15 | 43 | 77.2 | 72.0‡ | | 0.2 | 5.0* | +33.6 | +6.7 |
| | | | | 0.01** | | | | | | | | | |
| Po. | Amigen 5% | 72.2 | 0.32 | 0.32 | 0.0 | 19 | 60.4 | 55.4 | — | — | 5.0* | +12.8 | +2.5 |

*Theoretical—1 gm./day.
**This patient received food by mouth in addition to i.v. to this extent.
⊕Gelatin excretion after infusion stopped not determined.
‡Gelatin nitrogen excretion not done, only *total* nitrogen.

over long periods. The occurrence of thrombophlebitis following infusion with a casein hydrolysate is mentioned in some of the early papers concerned with its intravenous use, but most of the later reports on this subject fail to mention its occurrence. Thrombophlebitis appeared so important in this study that biopsies were taken of several veins after infusion to observe the character of the reaction.

The extent of the thrombophlebitis seen 3 days after infusion is shown in Figure 1 while Figure 2 illustrates an organizing thrombus 9 days after infusion. These infusions lasted 48 and 17 hours respectively. Many thromboses

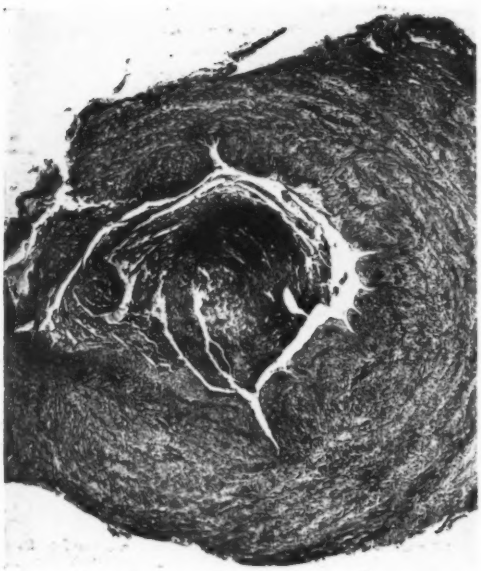

Fig. 1. Extent of thrombophlebitis seen 3 days after infusion.

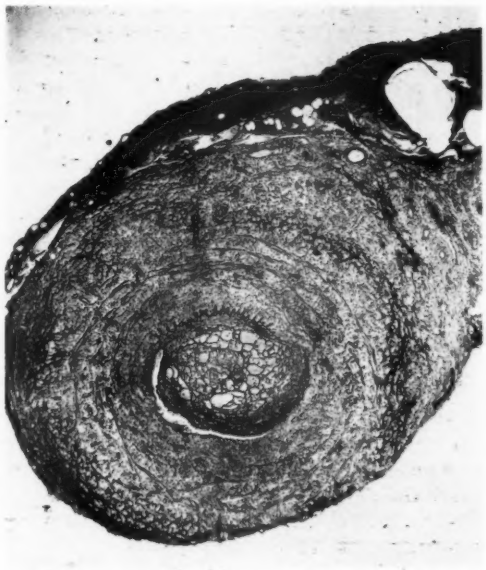

Fig. 2. An organizing thrombus present 9 days after infusion.

were seen following infusions of shorter duration. The individual tendency to thrombophlebitis seemed to be a more important factor than the degree of hypertonicity of the solution in determining how soon thrombophlebitis would occur. To cite extreme cases thrombosis occurred with 5 per cent glucose solutions in a few hours in a susceptible individual whereas another individual tolerated a 14 per cent solution of glucose, hydrolyzed protein and gelatin for over 4 days without changing the infusion site.

## DISCUSSION

It appears from these data, as from the data of others, that positive nitrogen balance is obtainable by parenteral means alone, even in the early postoperative period after extensive abdominal procedures. Comparison of the figures in Tables I and II does not indicate that hydrolyzed protein and glucose introduced by vein are any more efficient in bringing about nitrogen equilibrium than when they are given by mouth. In fact, it seemed to be a little more difficult to achieve equilibrium by the parenteral route with these materials.

It should be noted that not all patients can tolerate the intravenous infusion of 6 per cent gelatin solution in the amounts used here. Gelatin is a macromolecular colloid and increases plasma volume to a marked degree (4). When large amounts are used, there is danger of producing pulmonary edema, and in patients with poor cardiac reserve even small quantities may be harmful. In patients without circulatory symptoms, however, no difficulty was encountered in giving 0.15 gram of nitrogen per kilogram per day of gelatin nitrogen (about 1,000 c.c. of 6 per cent solution in 24 hours). The suggestion that gelatin might be utilized in the presence of the constituents of a complete protein was made by Brunschwig (1). The fact that the mixture of gelatin and hydrolyzed protein gave slightly better results than when all of the nitrogen was in the form of the derivatives of the complete protein is more surprising when one considers that about one-third of the gelatin was recovered unchanged in the urine. The amino nitrogen appearing in the urine, as determined in 5 patients with an intake of approximately 0.3 gram of nitrogen per kilogram per day, amounted

to only 7 per cent of the total nitrogen given in the 5 day period. This is somewhat greater than the amount of amino nitrogen found in the urine (4 per cent) of patients fed enterally at the same intake level. Elman, Charnas, and Davey have reported relatively low figures for amino nitrogen after infusion of hydrolyzed casein in experimental animals.

When the nitrogen intake was increased to 0.40 gram of nitrogen per kilogram per day by the parenteral route, positive nitrogen balance resulted for the 5 day period of study even when the caloric intake was low. This confirms, at least for the 5 day period, the findings of Elman (3).

The serum protein figures in the patients who received gelatin were low after infusion, reflecting the presence of the unnatural macromolecular colloid in the circulation. As the gelatin disappears from the circulation, the serum protein concentrations rise toward their former levels (5).

One lot of hydrolyzed protein had a very marked tendency to produce nausea and vomiting in each patient who received it. After the addition of gelatin, it was given to many of the same patients without causing this reaction.

With later commercial preparations such reactions were not troublesome, however, nor were pyrogenic reactions frequent. Occasionally after prolonged administration fever still occurs. The susceptibility of these nutrient solutions to contamination is very great. Even the so called closed systems are not entirely safe.

In our experience, however, the most frequent complication of the continuous intravenous infusion of nutrient mixtures in amounts sufficient to meet fully the nitrogen and caloric requirements of the postoperative patient is thrombosis. At present this appears to be the limiting factor preventing the extension of the method to a number of other problems, such as that of producing a preoperative weight gain in individuals with pyloric obstruction.

Although some patients develop thrombosis even with isotonic solutions, in general it may be said that the more hypertonic the solution the greater the tendency to thrombosis. From this standpoint the substitution of large molecular material, such as gelatin, for part of the small molecular material which constitutes the protein hydrolysates used for intravenous feedings, is a step in the right direction.

TABLE II.—ENTERAL FEEDING AT LEVELS TO COMPARE WITH PARENTERAL FEEDINGS*

| Patient | Feeding | Intake | | | Output | Balance |
|---|---|---|---|---|---|---|
| | | Total nitrogen | Nitrogen /kgm. /day | Calories /kgm. /day | Total nitrogen | Total nitrogen 5 days |
| | | grams | grams | | grams | grams |
| BE | Amigen | 78.7 | 0.27 | 26 | 65.3 | +13.4 |
| SC | Gastrostomy | 58.5 | 0.27 | 32 | 61.3 | −2.8 |
| PO | Gastrostomy | 64.5 | 0.28 | 31 | 72.7 | −8.2 |
| DO | Amigen+hosp. diet | 109.5 | 0.30 | 30 | 106.2 | +3.3 |
| BR | Amigen+hosp. diet | 88.2 | 0.30 | 33 | 77.1 | +11.1 |
| CL | Amigen | 75.0 | 0.30 | 33 | 69.6 | +5.4 |
| GA | Amigen | 100.0 | 0.30 | 34 | 81.4 | +18.6 |
| CH | Lactalbumin hydrolysate | 70.5 | 0.30 | 36 | 54.1 | +16.4 |
| BA | Lactalbumin hydrolysate | 98.0 | 0.30 | 37 | 91.1 | +6.9 |
| TO | Gastrostomy | 73.6 | 0.34 | 34 | 68.8 | +4.8 |
| BRU | Gastrostomy | 160.0 | 0.63 | 35 | 134.8 | +25.2 |

*From Table I-Ref. 6.

## SUMMARY AND CONCLUSIONS

Nitrogen balance studies were completed in 26 patients for 5 day periods during which food was provided parenterally by means of continuous intravenous infusions of solutions of glucose and various preparations of hydrolyzed protein. Gelatin produced for intravenous use was added in some instances to replace one-half of the hydrolysate, and in 3 instances it was used as the sole source of nitrogen.

Protein hydrolysates parenterally were no more efficient in producing nitrogen balance than were the enteral methods previously studied. In fact, the results were a little less satisfactory.

When gelatin was infused as the sole source of protein in 3 patients positive nitrogen balance was not obtained. However, when approximately one-half of the protein hydrolysate was replaced by gelatin, the results were slightly better than when all of the nitrogen was provided in the form of the hydrolysate.

Nitrogen intakes as high as 0.69 gram of nitrogen per kilogram per day were success-

fully given for 5 day periods. When the nitrogen intake was 0.40 and 0.47 gram of nitrogen per kilogram per day, positive nitrogen balance was observed in 2 patients who were in negative caloric balance (10 and 12 calories per kilogram per day respectively).

Untoward reactions were studied not only in these patients, but in other patients receiving protein hydrolysates in the surgical wards. Hyperpyrexia, local venous thrombosis and a characteristic symptom complex culminating in nausea and vomiting were observed. The addition of gelatin was of value in preventing the symptom complex culminating in nausea and vomiting. However, most of the more recently prepared material (1945) gave little trouble from this standpoint or from the standpoint of hyperpyrexia unless thrombosis appeared. All of the preparations when used for considerable periods resulted in thrombosis. This could not be entirely prevented by daily change of the infusion site but was delayed by the use of a plastic tube in place of a needle. The tendency was subject to marked variation between individual patients, and in several patients the infusion of hydrolyzed protein had to be stopped for this reason. Venous thrombosis appeared to be the chief limiting factor in parenteral nutrition.

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# ASPIRATION BIOPSY OF LYMPH NODES

## A Critical Review of the Results of 300 Aspirations

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THERE is a wide divergence of opinion regarding the diagnostic value of the aspiration biopsy (the withdrawal of tissue through a needle by suction), these attitudes ranging from absolute rejection to evangelistic overenthusiasm and overapplication.

Although the modern use of aspiration technique dates to 1930 at the time when Martin and Ellis (8) reported a simple method used by them at the Memorial Hospital in New York, only a few actual statistical results have been published. It is our purpose to evaluate the aspiration biopsy of lymph node enlargements as a diagnostic aid.

The material presented by these authors has been compiled from 300 consecutive biopsies of lymph nodes (245 patients, May 1942 to October 1945) seen at our hospital, an institution limited to the diagnosis and treatment of neoplastic diseases.

The hollow needle puncture for securing tissue for microscopic examination is not a new procedure. Grieg and Gray in 1904 aspirated material from lymph nodes to study the etiology of trypanosomiasis, but apparently not until 1915 was this method used to secure the cellular material occurring in lymphoblastomas (14). Goeller (1920) applied the principle to the use of a special trocar for securing prostatic material; Guthrie in 1921 reported observations on material collected by needle puncture and aspiration of lymph nodes in cases of Hodgkin's disease; and Forkner (1927) reported in considerable detail the structure of cells that are found in lymph nodes, both normal and pathologic, on both fixed and supravitally stained material which was obtained by passing a tiny, barbed dental broach through a small gauge needle which was inserted into the node.

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### PROCEDURE

The technique of securing aspirated material is essentially that described by Martin and Ellis (8, 9).

Materials required for the procedure are: (1) glass piston syringe (20 to 50 c.c.); (2) long (10 cm. or longer) aspiration needle (No. 17 to No. 15) with obturator; (3) Bard-Parker bistoury (No. 11 stab) blade; (4) novocain 1 per cent, and 2 cubic centimeter syringe with No. 25 hypo needle; (5) surgical lubricant; (6) skin disinfectant; (7) filter paper, fixative. The area to be aspirated is located and the overlying or adjacent skin infiltrated with novocain solution. The node is held steady by the disengaged hand until the procedure is completed. A skin nick is made with the bistoury blade to facilitate insertion of the needle and to prevent contamination of the specimen by bits of surface epithelium. The aspirating needle with the obturator inserted is then thrust through the skin nick and the node engaged with its tip. The obturator is carefully withdrawn, and the syringe (with its piston coated with surgical lubricant) is attached to the shank of the needle. Strong negative pressure is then maintained by partial withdrawal of the piston, and the needle advanced slowly into the mass with a rotary, back-and-forth motion. The needle is withdrawn to the edge of the mass and again inserted into it several times in slightly different directions. Negative pressure is then slowly released, the syringe disengaged, and the needle withdrawn. (If negative pressure is not released, the aspirated material may be spattered over the interior of the syringe, and some be lost.)

The obturator is now inserted and the core of material within the needle is pushed out upon a small (2 cm.) square of absorbent paper which is then placed in Zenker's solution with glacial acetic acid. *Negligence in following the details of this procedure results in failure.*

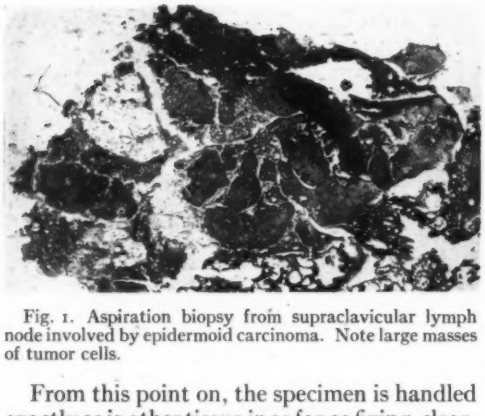

Fig. 1. Aspiration biopsy from supraclavicular lymph node involved by epidermoid carcinoma. Note large masses of tumor cells.

From this point on, the specimen is handled exactly as is other tissue in so far as fixing, clearing, embedding, and staining are concerned. Special stains can be made if necessary. Three slides should be made from each specimen, and 6 to 8 sections from each of 3 levels should be placed on each slide. Smears of aspirated material are not done in this laboratory for the reason that in our opinion they cannot give the sufficient additional information which the paraffin sections supply. These smears distort the architecture, and the diagnosis then must depend on the identification of individual cells.

The most satisfactory material aspirated consists of a plug of tissue of varying length, but this is usually dependent upon the nature and consistency of the aspirated mass (Fig. 1). Pseudocaseous or keratinoid material may be obtained from nodes containing epidermoid carcinoma; bits of soft gelatinous material may be secured from mucinous carcinomas, and in some cases, blood may be removed and the bits of tissue be contained in a blood clot. If a great deal of blood is secured, it may be placed in 2.5 per cent sodium citrate solution, shaken vigorously, and sections made of the centrifuged sediment. Fat is often secured, and in the region of the salivary glands, characteristic glandular tissue may be obtained. In successful cases, the histologic characteristics as well as the cytologic relations are maintained, the specimen differing essentially only in size from formal biopsy material.

### ADVANTAGES AND INDICATIONS

The necessity for biopsy and histologic diagnosis in the study and treatment of neoplastic diseases is unquestioned (6, 7), and it is equally true that under certain circumstances the aspiration biopsy has certain advantages over other methods of securing material (11, 12 13). The procedure may safely be employed in an out patient clinic, thus reducing or avoiding hospitalization, and the diagnosis may be obtained within 24 hours. Risk of infection is minimized. We have seen no case in which fungation from the needle puncture has occurred. Certainly when lymph nodes are aspirated this danger is more theoretic than actual, for if tumor is found, therapy can be instituted at once. The capsular defect left after needle puncture is inconspicuous compared to the

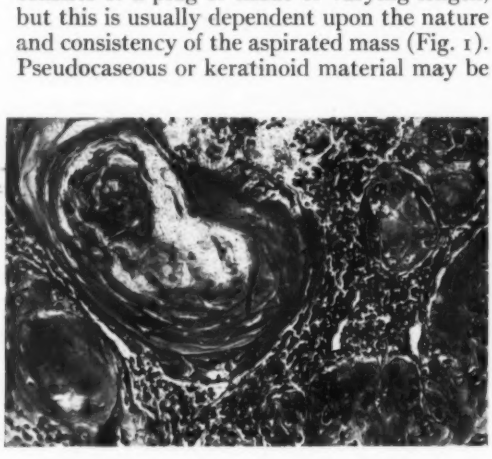

Fig. 2. Aspiration biopsy from cervical lymph node revealing well differentiated epidermoid carcinoma. Note epithelial pearl. Primary tumor arose in the larynx.

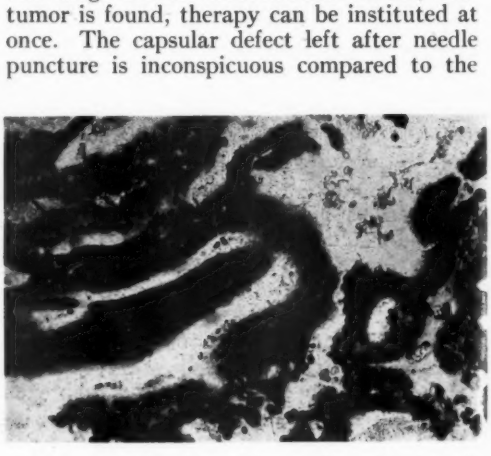

Fig. 3. Aspiration biopsy from axillary lymph node showing metastatic adenocarcinoma. Primary tumor arose in the breast.

large defect resulting from the usual incisional biopsy. No special training is required for securing or preparing specimens. (However, the experience and skill of the operator is reflected in the percentage success of his biopsies.) Evaluation of cure rates may also be facilitated in follow-up of treated patients. Operability or inoperability of a lesion may be determined by the presence of distant or regional node metastases. Histologic proof of the presence of a malignant tumor can be established for record purposes in clinically obvious cases. As in any other diagnostic methods, only positive results are conclusive. The aspiration should be repeated without hesitation, if it is found to be necessary; formal biopsy may be required, but little time is lost in either case.

The indications for aspiration biopsy of enlarged lymph nodes have been considerably extended, lacking valid contraindications and augmented by favorable experience in its accuracy and reliability. In general, any enlarged firm node which does not present an overlying ulcerated surface may be investigated by needle puncture and aspiration, especially if it is not easily accessible to surgical excision.

Martin and Morfit (10) felt that any lymph node enlargement (except cervical) in adults, exceeding 1 centimeter was presumptive evidence of abnormality. But the location of the node, its consistency, and the site and histologic character of possible primary tumor are

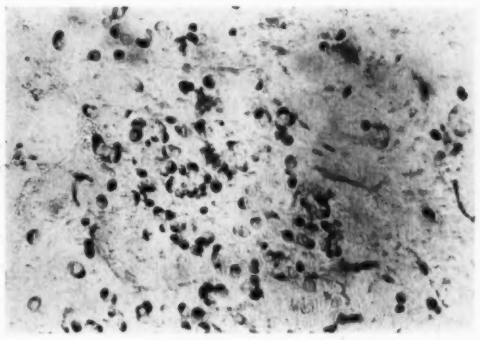

Fig. 4. Aspiration biopsy from supraclavicular lymph node. Metastatic adenocarcinoma. Primary tumor arose in the stomach.

factors which should have a bearing on whether or not a node is investigated. Obviously, the method finds greatest usefulness in tumor clinics for investigation of lymphadenopathy coexisting with a primary lesion, or for evaluation of nodes after treatment of a primary lesion.

In patients who exhibit peripheral lymph node enlargement as a presenting symptom, the nature of a possible primary lesion may be determined by microscopic examination of material aspirated from the adenopathy. Of the 3,896 cases reported by Martin and Morfit of patients having a cervical adenopathy as the only presenting symptom, 218 (0.06 per cent) indicated the existence of a silent primary neoplasm, as shown by aspiration bi-

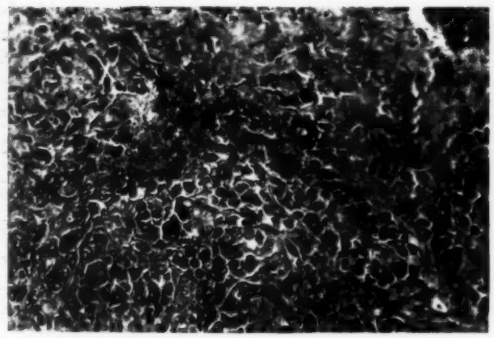

Fig. 5. Aspiration biopsy, cervical lymph node. Metastatic melanocarcinoma. Primary tumor arose in skin of the ear.

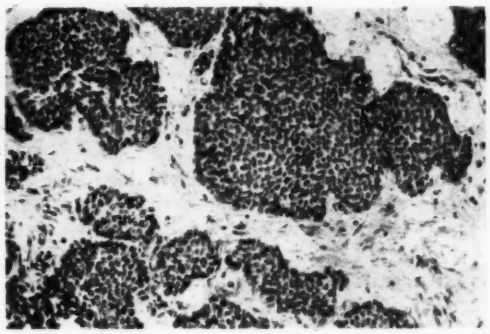

Fig. 6. Aspiration biopsy section from axillary lymph node. Metastatic carcinoma. The primary tumor arose in the breast.

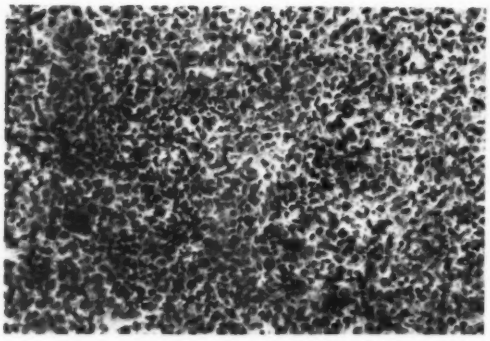

Fig. 7. Aspiration biopsy cervical lymph node. Lymphosarcoma.

opsy of the enlarged nodes. Absolute histologic proof of cancer in large regional nodes draining a foul infected lesion may indicate a radical course of treatment. Conversely, proof of a merely inflammatory enlargement of palpable nodes may prevent the performance of a radical procedure.

The one real disadvantage of aspiration biopsy as applied to peripheral lymph node enlargement is that only a small amount of tissue can be secured, and consequently it may be impossible to identify the details of capsular invasion and gross structural fine points. In such cases, which usually include Hodgkin's disease, lymphosarcoma, etc., an entire node should be taken for study by the usual routine technique.

*Primary lymph node* disease is best diagnosed by incisional biopsy in which such details as capsular invasion, architectural pattern, and reaction of perinodal tissues can be studied carefully. Hyperplastic and "neoplastic" diseases constitute the bulk of primary diseases of lymphoid tissue, if by the term "neoplastic" we include Hodgkin's disease, follicular lymphoblastoma, lymphosarcoma, and lymphatic leucemia. We are of the opinion that in lymph nodes the presence of other than lymphoid tissue is evidence of a secondary or a metastatic disease.

Recognition of *metastatic lymph node* enlargement is of the utmost importance in the choice of treatment. We believe that here aspiration biopsy offers the greatest degree of usefulness. It is self-evident that a broad knowledge of the clinical nature of malignant disease and its mode of spread is a primary requirement. The identification of metastatic lymph node involvement is not always possible, but the usual diagnostic cytologic and histologic criteria are just as applicable for metastatic disease as they are for primary neoplasms. The existence and the nature of a hidden primary lesion may be suggested by the pathologic changes within the lymph node and by its location in some particular lymph node area (Figs. 2, 3, 4, 5, and 6).

## RESULTS

Although this is a statistical review, the implications are clinical, so the results shall be discussed largely from this standpoint. In our study, the most common areas of lymph node metastases were in the cervical, submaxillary, axillary, inguinal, and supraclavicular areas. The sites of origin for these metastases were for the most part expected, but in a few instances a primary carcinoma behaved in a rather unpredictable manner. In the cervical region the most common site of origin was from within the oral cavity; in the submaxillary area, from the lower lip and tongue; and in the axilla, from the breast. In the supraclavicular area, 14 out of 24 originated in the breast. In the inguinal region, neoplasms of rectum, anus, cervix, vulva, and penis were responsible. Of these 5 large groups of nodes, the greatest percentage accuracy occurred in the supraclavicular group. The reasons for this are apparent, considering the infrequency with which that node group is affected by disease other than metastatic carcinoma. The accessibility of the supraclavicular region also leads to a larger percentage of successful biopsies.

The present study is based upon 300 aspirations performed on 245 patients who presented lymphadenopathy considered to suggest the existence of neoplasm. Diagnoses were originally made from all microscopic slides, the slides were recently reviewed, the diagnoses checked by one of us (L.V.A.), and review was also made of the subsequent clinical course of the patients and of further procedures which might affect the accuracy of previous diagnoses. In 7 cases originally reported negative,

TABLE I.—300 ASPIRATIONS ON 245 PATIENTS FROM MAY 1942 TO OCTOBER 1945

| Location | No. patients | No. aspirations | Group I successful | | Group II, Unsuccessful | |
|---|---|---|---|---|---|---|
| | | | No. revealing carcinoma | No. revealing lymphoid tissue | No lymphoid tissue obtained | No. patients later developing carcinoma |
| Cervical | 73 | 93 | 45 | 11 | 25 | 12 |
| Submaxillary | 47 | 61 | 31 | 7 | 15 | 8 |
| Axillary | 39 | 45 | 22 | 7 | 11 | 5 |
| Inguinal | 35 | 41 | 21 | 7 | 10 | 3 |
| Supraclavicular | 28 | 32 | 23 | — | 6 | 3 |
| Submental | 11 | 13 | 5 | 5 | 2 | 1 |
| Preauricular | 5 | 6 | 6 | — | — | — |
| Parotid | 2 | 4 | 3 | — | — | 1 |
| Retroauricular | 2 | 2 | 1 | — | — | 1 |
| Infraclavicular | 3 | 3 | 3 | — | — | — |
| Totals | 245 | 300 | 160 | 37 | 69 | 34 |

re-examination reversed the diagnosis to positive. In no case were a few questionable cells reported as tumor, and in no case was a false positive reported. In this limited series, clinical judgment of lymph node involvement in malignant disease was approximately 64.7 per cent correct, as verified by positive biopsies. The figure would undoubtedly be higher if it were not for the fact that all suggestive adenopathies were routinely investigated; they were not necessarily considered malignant. Five aspirations revealed primary lymphomas, later verified by conventional biopsy. Of these, the cervical region was the site of involvement in 3 cases; submaxillary, in 1; and axillary, in 1. Lymphosarcoma was diagnosed 4 times (Fig. 7) and Hodgkin's disease, once. Tuberculosis was diagnosed in 4 instances, and was proved either by means of animal inoculation or acid-fast stain.

One hundred and ninety-seven of the 300 aspirations were considered "successful" in that either tumor or lymphoid tissue was secured. One hundred and three cases represented technical failure to obtain sufficient tissue, but subsequent clinical course or further diagnostic procedures proved only 34 of these to be in error (11.1 per cent of total aspirations.)

Forty-two cases were diagnosed as "lymphoid tissue," and only 5 of these were proved subsequently to be incorrect, placing them in the "wrong" classification (a technical error of 11.9 per cent). It is thus apparent that a node may contain tumor in another portion, or more commonly, material from an adjacent uninvolved node may be aspirated and thus, normal-appearing lymphoid tissue be obtained. But if tissue sufficient for diagnosis is secured, our series indicates that one may assume (within 11.9 per cent error) that the diagnosis is correct. The 69 cases in which "no lymphoid tissue" was reported represent technical failure to obtain lymph node material by means of aspiration, but not failure of diagnosis, for they represent cases in which subsequent follow-up proved no malignant condition to have been present.

## SUMMARY AND CONCLUSIONS

Aspiration biopsy in our experience provides a reliable, safe, rapid, and economical method of investigating lymph node enlargements, the accuracy of which within limits of application, very creditably approaches that of other similar diagnostic procedures. The greatest value of the method lies in the evaluation of nodes suspected of being the site of metastatic disease, particularly those regional nodes approximating foul and infected primary lesions. The diagnosis of lymphomas was invariably suggested, but exact classification could not consistently be made.

The relative merit and indications of incisional or formal biopsy are adjunctive rather than competitive. The decision as to operability or inoperability, or the choice of treatment is facilitated by the establishment of the presence or almost certain absence of metastases in enlarged nodes.

Aspiration biopsy also provides an accurate method of determining the presence of metastasis in patients to be treated by roentgentherapy and the size of the field may be chosen accordingly. Empirical treatment based on clinical judgment alone can be avoided, as well as the delay in treatment occasioned by waiting for an incision to heal.

It should be emphasized that the diagnoses which were made in these aspiration biopsies

were based entirely on *paraffin sections and not on smears.*

Successful aspiration biopsy as a safe and reliable diagnostic procedure is a product of the combined resourcefulness, the clinical acumen, the technical ability, and the mutual sympathetic co-operation of surgeon and pathologist who are trained to recognize malignant disease.

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# STRENGTH-INTERVAL CURVES AND REPETITIVE STIMULI IN ELECTRODIAGNOSIS

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REPETITIVE stimuli have been used by physiologists and clinicians to study the kinetics of stimulus for many years. The best known repetitive stimulus used by clinicians has been the faradic current. Because, however, it usually has an uncontrollable waveform, is variable in duration, amplitude, and repetition frequency, it is of limited value for obtaining data.

Another repetitive stimulus often used by physiologists is the alternating sine wave of variable frequency. Since there is no appreciable time interval between stimuli, it does not correspond to the conditions studied in this work.

Repetitive stimuli separated by a controllable interval of time have been studied chiefly by physiologists. For example, there are the paired stimuli as studied by, among others, Hill and Solandt; the recurrent discharges of condensers studied by Lapicque, Chauchard and Albert; and unidirectional periodic current or Leduc current studied by May.

The data obtained from such studies have been plotted as strength-frequency curves in which the frequency was changed by varying both the duration of the stimulus and the time interval between stimuli. The data were also plotted as strength-interval curves in which the duration of the stimuli was held constant and the time intervals between them varied.

Because the duration of stimuli and likewise the time intervals between them varied so much from investigator to investigator, the literature contains very few clues which aid one in selecting appropriate values for electrodiagnosis. For example, for the purpose of his investigation it was necessary for Solandt to use stimuli lasting 2,000 milliseconds. Lapicque, Chauchard and Albert used time intervals between stimuli ranging from 833 to 2,000 milliseconds. Only by analysis of these data as well as those of Scott and May could one find some suggestions applicable to our problem.

From such analysis it appeared that characteristics to be studied were (1) *Addition Latente*, or recruitment, (2) the profile of the strength-interval curve, and (3) a search for a possible optimum interval and limiting interval time.

## MATERIAL AND METHOD

The material consisted of 6 cats in which section and immediate suture of the left sciatic nerve was done.

The first strength-interval curves were obtained on about the 7th postoperative day and at approximately weekly intervals thereafter until clinical recovery was well advanced.

For this study, a constant current impulse stimulator was designed by one of us (J.G.G.) and Mr. J. A. Fizzell which entailed the following features: (1) constant predetermined values of stimulating current irrespective of rather great changes in tissue impedance; (2) seventeen durations of stimulating current ranging from 1 millisecond to 1500 milliseconds, these selected to conform to a logarithmic scale; (3) nine values of intervals between stimuli, ranging from 1 to 4,000 milliseconds (Fig. 1).

In making a systematic approach to the problem mentioned above, we elected to hold the duration of the stimulus constant at 5 milliseconds and to vary the durations of the interval, employing those of 1, 5, 10, 15, 20, 25, and 30 milliseconds. When the duration of stimuli was held constant at 1 millisecond, it was found that some time after section, the threshold exceeded the amount of available current.

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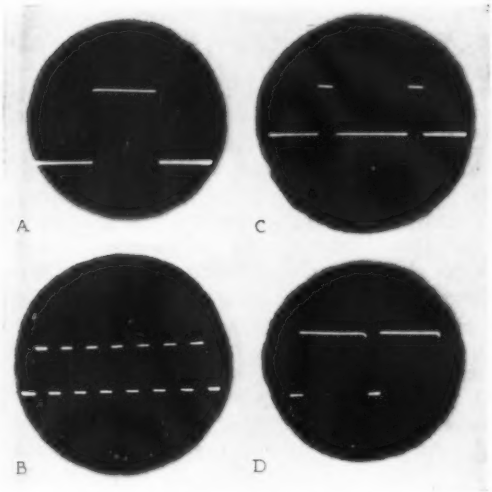


Fig. 1. Oscillograms of constant current stimuli. A, Single stimulus of 1 millisecond's duration; B, repetitive stimuli—1 millisecond's duration, 1 millisecond's interval; C, repetitive stimuli—1 millisecond's duration, 5 milliseconds' interval; D, repetitive stimuli—5 milliseconds' duration, 1 millisecond's interval.

## RESULTS

*Facilitation and inhibition.* Kries and Sewall called attention to what was called *Addition Latente* in 1881.

Facilitation or recruitment has been expressed as follows: A very short subthreshold stimulus leaves behind it a local change of excitability which gradually dies away, so that a second subthreshold stimulus, although separated from the first by a finite time interval, may sum with it and become effective.

The change of excitability has been said by Hill and Solandt to depend upon the function of accommodation and from curves obtained by them, they measured the time rate of accommodation.

It was pointed out by Lapicque that *Addition Latente* occurs when the duration of each stimulus is brief as compared to the chronaxie. As will be seen, this is usually true when the intervals are of short duration; but if the intervals are of longer duration not only does facilitation cease, but actual inhibition may occur.

The term "facilitation" as defined above denotes that a muscle is more excitable to repetitive stimuli having a specified duration and time interval than to a single stimulus of the same duration. The term "inhibition" on the other hand denotes that a muscle is less excitable to repetitive stimuli than to a single stimulus. For the purpose of showing how facilitation and inhibition vary during the periods of degeneration, denervation, and regeneration, it is desirable to express these two terms in some mathematical form. One convenient method of doing this is to take the ratio of the threshold current for a single stimulus of a certain duration to the threshold current for repetitive stimuli of the same duration and plot this number as a function of postoperative days on suitable graph paper. The ratio just described may be termed the facilitation ratio, and expressed in equation form it becomes:

$$\text{Facilitation ratio} = \frac{I_s}{I_r}$$ where $I_s$ = the threshold current for a single stimulus and $I_r$ = the threshold current for repetitive stimuli.

When using this equation, a ratio of 1.0 indicates the condition where neither facilitation nor inhibition exists. Facilitation is present when this ratio is a number greater than 1.0 and, conversely, inhibition is present when this ratio is a number less than 1.0. The curves in Figures 2, 3, 4, and 5 have been computed by means of the facilitation ratio formula just described and plotted on semilogarithmic coordinate paper.

In our study, the durations of the stimuli were 1 and 5 milliseconds. When the duration of the stimulus was only 1 millisecond it was found that as denervation occurred the threshold rose to such a degree that often data could not be obtained. Therefore, in this study we will report the data resulting from stimuli of 5 milliseconds' duration with intervals of 1, 5, 10, 15, 20, 25, and 30 milliseconds.

The liminal response of muscle to repetitive stimulation is a twitch. Although this end point is difficult to reproduce, the data obtained in this manner will be reported since they may become valuable in mathematical treatment of the kinetics of stimulus. Since facilitation was observed best when the interval was 1 millisecond, the first study was made using a stimulus of 5 milliseconds and an inter-

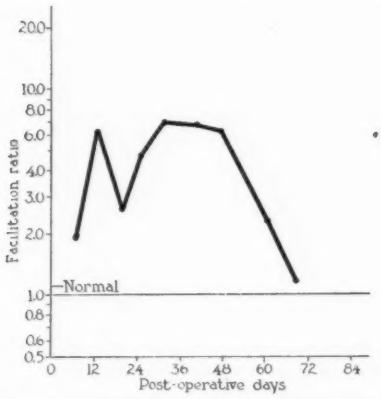


Fig. 2. Facilitation ratio expressing both facilitation and inhibition versus postoperative days. The duration of the stimulus was 5 milliseconds; the interval was 1 millisecond; the end point was a twitch. Facilitation ratio = $I_s/I_r$ where $I_s$ = the threshold current for a single stimulus and $I_r$ = the threshold current for repetitive stimuli.

val of 1 millisecond. We shall describe first the change in the facilitation noticed during the periods of degeneration, denervation, and regeneration using a twitch as the end point.

In the normal, the facilitation ratio ranged from 1.1 to 1.7, with an average value of 1.3. Following section and suture of the sciatic nerve of the cat, the evaluation of changes in facilitation and the facilitation ratio followed closely the changes in rheobase and galvanic tetanus ratio. Thus, early in degeneration there was an increase in the facilitation ratio followed by a decrease and secondary increase. During denervation, the ratio became the highest but early in regeneration, it dropped off and usually was at a low value by the 70th postoperative day. It should be pointed out that in several cases there was a decrease and increase in the ratio early in regeneration which was then followed by a progressive diminution in the ratio to a low value. In several instances, the ratio became less than 1.0 during the period of regeneration thus indicating that inhibition was present (Fig. 2).

When, on the other hand, the duration of the stimulus was 5 milliseconds and the interval between stimuli was 30 milliseconds, inhibition was observed in some cases during early degeneration and was present in all cases during late regeneration. It is to be remembered that a facilitation ratio of less than 1.0 denotes inhibition (Fig. 3).

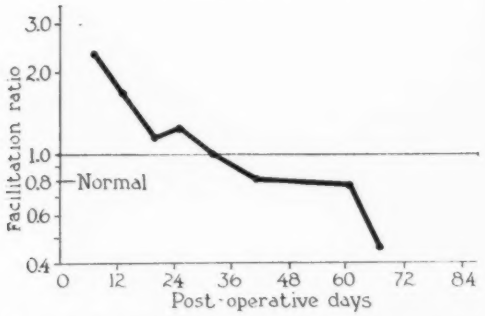


Fig. 3. Facilitation ratio expressing both facilitation and inhibition versus postoperative days. The duration of the stimulus was 5 milliseconds; the interval, 30 milliseconds; the end point a twitch.

Because the liminal twitch is difficult to reproduce, as in the case of other investigators, we have preferred to use sustained tetanus as the end point of stimulation. Under this condition in the case of normal muscle, the threshold current for repetitive stimuli usually diminished as the time interval between stimuli was increased. Following section and suture, there was an initial increase in the facilitation ratio followed by a sharp decrease to below 1.0 indicating inhibition. During denervation the greatest facilitation occurred and during the period of recovery, there was a continued decrease in the ratio occasionally followed by a temporary increase but leading to a final inhibition (Fig. 4).

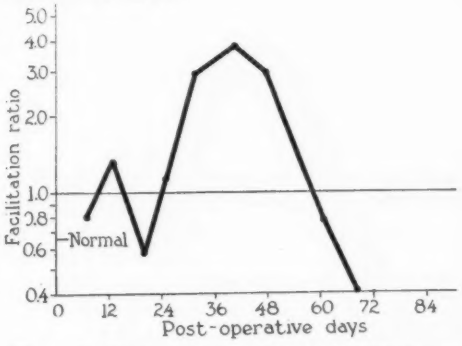


Fig. 4. Facilitation ratio expressing both facilitation and inhibition versus postoperative days. The duration of the stimulus was 5 milliseconds; the interval, 1 millisecond; the end point, tetanus.

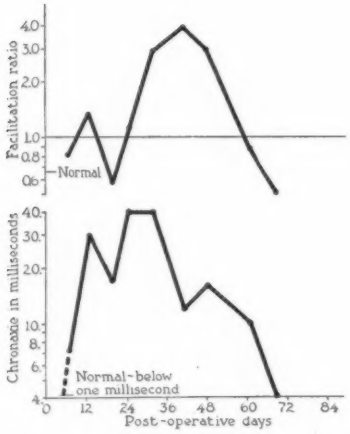


Fig. 5. Comparison of the facilitation ratio to chronaxie on various days after operation. The duration of the stimulus was 5 milliseconds; the interval, 1 millisecond; the end point, tetanus.

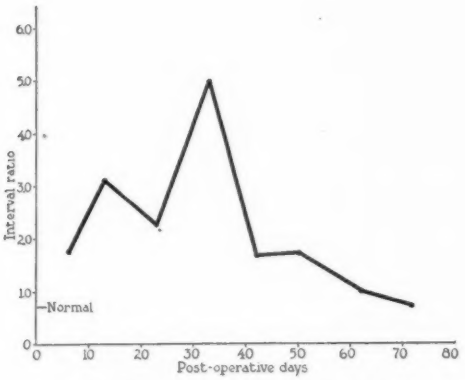


Fig. 6. Interval ratio versus postoperative days. The duration of the stimulus was 5 milliseconds in each instance. Interval ratio = $T_{15}/T_1$ where $T_{15}$ = the threshold current for an interval of 15 milliseconds and $T_1$ = the threshold current for an interval of 1 millisecond.

Confirming Lapicque's observation, it was found that with intervals of short duration a lengthening of chronaxie was accompanied by an increase in the facilitation ratio and, conversely, when the chronaxie shortened, the facilitation ratio decreased (Fig. 5).

### THE PROFILE OF STRENGTH-INTERVAL CURVES

Lapicque said, "..... in the case of muscle directly stimulated by means of a given capacity, the liminal voltage is constant for very small intervals; then as the interval increases, it goes up gradually until it reaches the threshold of an isolated stimulus (infinite interval)." This should not be misinterpreted as meaning a stimulus of infinite duration, which would be the rheobase value of voltage.

May also reported that with stimuli of 5 milliseconds' duration, the strength of the contraction increased with increasing frequency to 120 per second and then remained constant. It is permissible for us to assume that for liminal stimulus the threshold would have diminished with shorter intervals. This we were unable to confirm in the case of normal muscle. On the contrary, we found that as the interval increased up to 30 milliseconds the threshold diminished, as was the case in Solandt's work.

In a few instances, an optimum interval was observed as had been observed by May. However, an optimum interval was at times more clearly demonstrated on the 6th or 7th postoperative day.

In a strength-interval curve obtained from degenerating, denervated, and early recovering muscle, the magnitude of the threshold current generally rises as the length of the interval is increased, according to the state of muscle, whether denervated or recovering; this continues up to a point where a plateau is reached and a further lengthening of the interval causes no further rise in the threshold. In fact, as recovery occurs the threshold may even decrease. This interval at which the plateau is reached is known as the "limiting interval." At about the 7th postoperative day the strength-interval curve is so nearly flat that there is no definite limiting interval. During the period from about the 7th to the 40th postoperative day, the limiting interval becomes longer and longer until recovery begins.

At the 40th postoperative day in some cases no plateau was noticed even at an interval of 30 milliseconds. Thereafter, as neurotization was taking place, the limiting interval began to reappear at shorter intervals until at the 70th postoperative day the strength-interval curve became nearly flat and resembled the

normal. Although this phenomenon of "limiting interval" was observed in all cases, the lack of uniformity with which the limiting interval diminished during the process of neurotization seems to us to render it an inaccurate index of recovery.

On the other hand, the steepness of the rise of the strength-interval curve was seen to change appreciably during the periods of degeneration, denervation, and regeneration. For example, the rise of the curve for denervated muscle was usually quite steep. However, as recovery began and progressed, the rise became less and less steep finally, at about the 70th postoperative day, the curve was almost flat. These changes in the rise of the curve can be visualized quite readily if one plots the ratio of only two points on the strength-interval curve as a function of postoperative days.

The points we elected to use were the threshold current for an interval of 15 milliseconds and the threshold current for an interval of 1 millisecond, the duration of the stimulus being held constant at 5 milliseconds. The ratio obtained by dividing the threshold current for an interval 15 milliseconds by the threshold current for an interval of 1 millisecond is termed the "interval ratio," and is plotted as a function of postoperative days (Fig. 6). It should be remembered that a high interval ratio denotes a steep rise in the strength-interval curve whereas a low ratio denotes a more gradual rise, or even a flat curve.

In the normal, the interval ratio is usually less than 1.0 and occasionally, during early degeneration, a ratio of less than 1.0 was observed. As denervation progresses, however, the ratio becomes some multiple of 1.0 and by the 30th to 40th postoperative day has reached its highest value, at times as high as 5.0. As regeneration began and progressed, the ratio took on smaller and smaller values until about the 70th postoperative day, when it again became a number less than 1.0.

## APPLICATION TO MAN

When we began to study strength-interval curves in man, we had no guide as to which duration of stimulus and time interval between stimuli would give the most satisfactory data. We elected to use a stimulus of 1 millisecond's duration and intervals of 1, 5, and 12 milliseconds respectively.

This proved to be an unfortunate choice for two reasons. First, when a muscle is denervated, it is often impossible to obtain data for a single stimulus of less than 14 to 30 milliseconds' duration, a fact which prevented us from making a quantitative study of facilitation and inhibition. Second, because the threshold values of current for the longer time intervals increased so rapidly, especially during denervation, we were unable to obtain satisfactory data studying the steepness of rise of the strength-interval curve.

Although we are able to say from data obtained in human material that a flat strength-interval curve is indicative of advanced recovery, we feel that the subject of strength-interval curves for electrodiagnosis in man needs restudy.

It is suggested, for the benefit of those who may desire to undertake such an investigation, that a stimulus of 30 milliseconds' duration and time intervals of 1, 5, and 15 milliseconds be tried. This would ensure the obtaining of data for a single stimulus at all times and permit an evaluation of facilitation and inhibition. In addition, a stimulus of 5 milliseconds' duration should give satisfactory data for studying the steepness of the rise of the strength-interval curve after injury to the nerve.

From our investigation it would appear that longer intervals than those mentioned above could offer very little because a limiting interval soon occurs for a stimulus having a duration of 20 or more milliseconds.

## SUMMARY

We have reported on the experimental data obtained from strength-interval curves in the tibialis anticus muscle of the cat during the periods of degeneration, denervation, and regeneration following section and immediate suture of the sciatic nerve. While changes in facilitation ratio obtained using a twitch as an end point were described to permit of any study of the kinetics of stimulus, it was pointed out that the change in facilitation ratio obtained when using tetanus as the end point gave a more accurate and critical assessment

of the muscle on the various postoperative days. Attention was then called to the fact that the limiting interval was an unsatisfactory index of recovery because of the lack of uniformity with which it diminished during the process of neurotization. It was next shown that the steepness of the rise of the strength-interval curves which was expressed in terms of an interval ratio gave reliable information as to the state of the muscle on the various postoperative days.

The applications of strength-interval curves for electrodiagnosis in man were discussed and at that time we pointed out the reasons for our failure to obtain satisfactory data in a large number of cases. We then suggested several changes in technique which should be useful to future investigators in this field.

## CONCLUSIONS

1. *Addition Latente*, or facilitation, whereby the threshold for repetitive stimuli of short duration is less than that for a single stimulus of same duration, was found in normal muscle.

2. Facilitation was found to be greatest in completely denervated muscle.

3. With the beginning of regeneration, facilitation progressively diminished and finally inhibition occurred.

4. Although during the period of degeneration and regeneration a limiting interval was found, it proved inconclusive in making a diagnosis.

5. The steepness of the rise of the strength-interval curve becomes greater as degeneration progresses, is greatest during denervation, and becomes less and less during recovery.

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# CECOSTOMY AND THE MILLER-ABBOTT TUBE

## A Report on their Combined Use in the Preparation of the Obstructed Large Bowel for Surgery

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DECOMPRESSION and preparation of the colon preliminary to resection of obstructing neoplasms of the left colon are usually accomplished by cecostomy or transverse colostomy. There are several difficulties associated with both methods. A cecostomy accomplishes decompression without complete defunctioning and does not usually permit cleansing of the bowel proximal to the lesion. For these reasons it may be inadequate, and a transverse colostomy may be required for proper preparation of the bowel before resection of the growth. A defunctioning transverse colostomy permits irrigation of the isolated bowel proximal to the lesion, and is in that respect preferable to cecostomy, but it necessitates a further major operative procedure—not without hazard—namely, that of closure.

For these reasons the author has sought a more adequate method of large bowel preparation, using a cecostomy and, therefore, not requiring secondary closure. Such a method is the subject of the present communication.

Decompression by cecostomy is performed according to the method of Allen and Welch. Figures 1 and 2 show diagrammatically the type of cecostomy used and the manner in which the Miller-Abbott tube is inserted. A large cecostomy tube of 20 millimeter diameter is recommended. Following this procedure, a few days of rest are felt advisable so that the colon may regain its tone and resume peristalsis. Three or 4 days have been found quite adequate. A small hole is then cut in the superior aspect of the rubber drainage tube close to its attachment to the cecostomy tube, and a Miller-Abbott tube (1, 4) (preferably size No. 18) is passed into the cecum, and the balloon then inflated with 60 to 120 cubic centimeters of air. The curved passage through the cecostomy tube offers such resistance to the Miller-Abbott tube that it must be manually urged into the cecum. What slack is available in the cecum is readily taken up by the action of peristalsis on the balloon. If the Miller-Abbott tube is readjusted and slack placed into the cecum as often as every 10 minutes, the tip of the tube may reach the sigmoid flexure within 3 hours. The tube appears to progress equally well on or off suction, and it is advisable not to use suction at this time lest the tube become occluded. When the cecum will no longer accept slack tube, it is probable that the obstructing lesion has been reached. This fact may be checked by x-ray examination; the balloon is then deflated and the tube is made fast externally by strapping it to the cecostomy. Even though a maximum of a yard of tube is necessary, we have not shortened the Miller-Abbott tube because its length has not interfered with its function in these cases.

Irrigations through the Miller-Abbott tube of 1500 cubic centimeters of normal saline solution or tap water twice daily will "back-flush" the colon from the point of obstruction and the drainage will flow from the cecostomy tube. Following each irrigation the Miller-Abbott tube is placed on Nelson or Wangensteen suction for 30 minutes to empty the bowel lumen of residual irrigating fluid and to maintain the bowel in a state of decompression. Following this a suspension of sulfathalidine has been instilled into the Miller-Abbott tube in some patients. Regardless of this use of sulfathalidine, there has been no gross difference in the appearance of the bowel at the time of resection and open anastomosis. We have found it convenient to use the ordinary "intravenous" saline flasks and tubing, as the connections fit the Miller-Abbott tube. In a day

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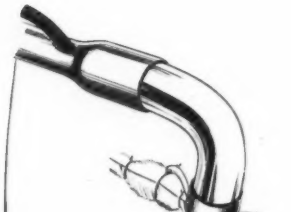

Fig. 1. Diagrammatic sketch of cecostomy incision, cecostomy tube, and insertion of Miller-Abbott tube.

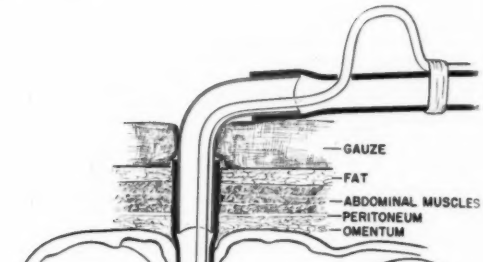


Fig. 2. Diagrammatic sketch in longitudinal section showing manner of insertion of cecostomy tube and of Miller-Abbott tube. The cecum is closed about the cecostomy tube by 3 invaginating pursestring sutures, the first being of No. 0 plain catgut which includes a bite into the tube itself for fixation, the remaining 2 being of No. 0 chromic catgut. The omentum is wrapped about the cecostomy tube prior to closure of the abdomen. The right angle glass tube with its attached rubber tubing is used to prevent kinking and has an inside diameter of 20 millimeters.

or so the obstructing lesion may open sufficiently to permit the irrigations to be given with the patient on the bedpan, as both rectal and retrograde colonic irrigation may take place.

Resection can be carried out on a clean bowel when the patient is adequately prepared systematically to withstand the procedure, often about 10 days after cecostomy. The last irrigation is given 2 or 3 hours prior to

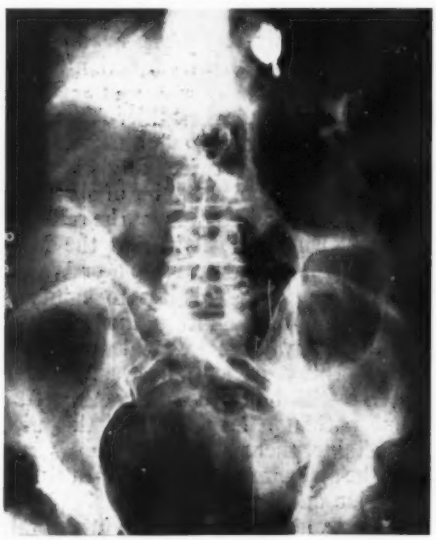

Fig. 3. Case 1. X-ray film on entry showing marked distention of the colon.

**Fig. 4. Case 1.** X-ray film showing the passage of the Miller-Abbott tube 3 hours after insertion.

operation and is followed by suction. Both sulfathalidine by mouth, 6 to 8 grams daily, and a low residue diet are indicated to keep the cecostomy drainage of such a character as to allow the Miller-Abbott tube and the cecostomy tube to function at their best.

It is suggested, though this procedure has not yet been put to the test, that cleansing of the distal limb of the bowel in transverse colostomies may also be successfully accomplished through the use of the Miller-Abbott tube and irrigations.

CASE 1. M. D., No. 546942 (Figs. 3 and 4.), a 73 year old woman, entered the Massachusetts General Hospital with a story of complete large bowel obstruction of 48 hours' duration. An x-ray examination of the abdomen showed a markedly distended large bowel, and a barium enema revealed total obstruction in the region of the proximal sigmoid flexure. A cecostomy was performed with satisfactory decompression, and by the fourth postoperative day she had regained normal peristalsis. A Miller-Abbott tube was passed through the cecostomy, and irrigations were instituted. Eleven days following the initial procedure, resection and open end-to-end anastomosis were carried out, at which time the bowel was clean and decompressed with no visible fecal matter. There was also no discrepancy of significance in the diameter of the two limbs of sigmoid at the point of anastomosis.

CASE 2. S. DeG., No. 547698 (Figs. 5 and 6), a 69 year old man entered the Massachusetts General Hospital with a story of complete bowel obstruction of 48 hours' duration. An x-ray examination of the abdomen showed dilated small and large bowel. Barium enema demonstrated an obstructing lesion in the midsigmoid consistent with carcinoma. A Harris tube was passed into the small bowel; but, as improvement did not occur in the course of 48 hours, cecostomy was performed with fair decompression. On the third postoperative day, peristalsis had returned to normal, and a Miller-Abbott tube was passed through the cecostomy and irrigations were instituted. Sixteen days after cecostomy, resection and open end-to-end anastomosis were carried out. At this time the bowel was clean and well decompressed with no feces present grossly and no significant discrepancy in the diameter of the bowel proximal and distal to the resected area.

CASE 3. E. W., No. 552309,[1] a 64 year old woman entered the hospital with partial large bowel obstruction and a distended cecum secondary to a carcinoma of the rectum. Cecostomy was carried out with good decompression, and 5 days later a Miller-Abbott tube was passed through the cecostomy. Irrigations were instituted, and 12 days following her initial procedure a combined abdominoperineal resection of her rectum was performed. At this time the bowel was found completely decompressed and in very satisfactory condition for the resection.

CASE 4. A. B., No. 472577, a 75 year old man entered the Massachusetts General Hospital with 4

[1]Courtesy of Dr. E. Parker Hayden.

Fig. 5. Case 2. X-ray film on entry showing distention of small and large bowel.

Fig. 6. Case 2. X-ray film showing the passage of the Miller-Abbott tube 2 hours after its insertion.

days of total large bowel obstruction from an extensive carcinoma of the rectosigmoid. Cecostomy was performed, and 4 days later a Miller-Abbott tube was inserted into the cecostomy and irrigations instituted. Despite much impacted barium in the ascending colon, the Miller-Abbott tube progressed slowly and steadily to reach the splenic flexure in 2 days. Fourteen days following cecostomy, exploratory laparotomy was carried out and a permanent sigmoid colostomy made because the growth was found to be locally inoperable. At this time the bowel was found to be completely cleansed.

CASE 5. M. D., No. 548717[1], a 67 year old woman entered the hospital with a story of progressive, recurrent attacks of gaseous distention and abdominal cramps, culminating in nearly complete large bowel obstruction for a month prior to entry. Barium enema showed an extensive area of rather marked narrowing in the mid and upper sigmoid flexure. Cecostomy was performed; and, on the fourth postoperative day when peristalsis had resumed normal activity, a Miller-Abbott tube was passed through the cecostomy. It progressed without difficulty, and irrigations were started. On the fifteenth day after cecostomy, resection of an area of diverticulitis in the lower sigmoid flexure and open end-to-end anastomosis were done. At the time of resection, the bowel was deflated but had a minimal amount of feces present. This patient had no irrigations or suction applied through her Miller-Abbott tube during the 24 hour period prior to operation.

CASE 6. M. G., No. 82841[2], a 60 year old woman entered the hospital with a story of subacute large bowel obstruction of 14 days' duration. Barium enema showed complete obstruction from below at the splenic flexure. Cecostomy was performed with poor decompression, and the patient continued to have a moderately dilated colon proximal to the obstruction, with associated cramps. On the tenth postoperative day a Miller-Abbott tube was passed without difficulty through the cecostomy, and irrigations were instituted—with complete relief to the patient and clinical decompression of the colon proximal to the obstruction. Four days following passage of the Miller-Abbott tube, resection of the carcinoma of the splenic flexure with open end-to-end anastomosis was carried out, at which time the bowel was deflated and clean.

[1]Courtesy of Dr. Arthur W. Allen.
[2]Courtesy of Dr. Joe V. Meigs.

## SUMMARY

A method of preparing patients with obstructing lesions of the left colon for resection is presented, together with several illustrative case reports. This method consists of cecostomy and the passage of a Miller-Abbott tube through the cecostomy for the purpose of "back-flushing" the colon by irrigations. It is also useful for postoperative decompression of the anastomosis. It is felt that this method offers advantages over cecostomy alone, and it is also believed to be superior to a transverse colostomy because a secondary operative closure is not required.

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# SUPRACONDYLAR SHORTENING OF THE FEMUR FOR LEG LENGTH INEQUALITY

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LENGTH inequality of the lower limbs in the growing child may be corrected by elective arrestment of growth of one or more growth cartilages of the longer limb as described by Phemister. After puberty the rate of longitudinal growth from the femoral and tibial growth cartilages declines and marked length discrepancy usually cannot be corrected by this method. In the adolescent or adult with excessive length inequality the deformity can only be corrected by shortening the longer limb or lengthening the shorter extremity.

Individuals with one deformed leg frequently object to the risk of impairment of the sound limb occasioned by surgical shortening. Experience has shown, however, that leg shortening is associated with few complications when compared with leg lengthening. The formidable procedure of lengthening with its greater incidence of nonunion, postoperative infection, or traction damage to nerves, vessels, and muscle leaves many surgeons reticent to perform such a procedure. This is particularly so where marked disuse atrophy of bone and soft tissues provides unfavorable conditions in the short limb. Partially paralyzed muscles may be weakened by lengthening, and ankylosis of a joint on either side of a lengthened long bone increases the hazard of fracture through the site of the lengthening. The relative safety of femoral shortening permits wider application of this method of leg length equalization than is the case with femoral lengthening.

The usual site of election for shortening the femur in published cases is the diaphysis. It is the purpose of this paper to describe the technique used, and end-results of 15 cases in which shortening was accomplished by resection of bone from the lower femoral metaphysis.

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## PRINCIPLES INVOLVED IN LEG SHORTENING

The object of shortening is to equalize the length of the limbs or to reduce the discrepancy to an amount compatible with good function. Leg length inequality of less than 1 inch is seldom of functional significance. A discrepancy of 1 inch or more may be sufficient to impair gait, appearance, and dynamics of the back or unaffected limb. Lengthening the shortened limb is esthetically more desirable from the patient's standpoint but the decision to shorten the longer limb or lengthen the shorter leg can be made only after comprehensive study of the individual case.

Leg shortening usually should be performed near the end of the growth period. The accuracy with which equalization is accomplished by this method is nullified if subsequent unequal growth occurs. The earlier decline in the rate of growth of the lower extremities in girls generally permits operative shortening at the age of 12 or 13 years. In boys, in whom puberty occurs later and growth from the lower extremity is relatively greater, equalization by shortening should be delayed until 14 or 15 years of age. Final decision rests in correct evaluation of the maturity of the individual at a given age based on knowledge of his hereditary background, bone age, and growth expectancy of the sound limb as well as the affected leg.

Flexion-adduction deformity of the hip, or any angulation deformity of the limb must be corrected before evaluation of actual leg length inequality is possible. Correction of fixed hip deformity is usually done near the end of the growth period if recurrence of the deformity is to be prevented.

In patients with weak hip abductors, or inability to elevate the pelvis on the short limbed side, ½ to 1 inch of residual shortening of the leg facilitates walking. This also may be true in patients with ankylosis of either a hip or knee.

Fig. 1. Drawing showing the technique of resection of bone from the metaphysis and method of end-to-end fixation over an intramedullary peg with screws or threaded pins.

The maximum correction advisable by shortening in the lower ⅔ of the femur is about 3 inches. Shortening in excess of this amount may produce permanent quadriceps weakness. If length inequality is more than 4 inches, shortening the longer limb may be preceded by lengthening the shorter leg. Partial equalization of length by resection may be advisable if the patient would be rendered unduly short of stature, leaving a difference of 1 or 2 inches to be compensated for by a built-up shoe. These factors should be considered in planning any length equalization procedure.

### CAUSES OF UNEQUAL LEG LENGTH

Congenital anomalies accounted for marked length discrepancy of the legs in 3 cases reported here. Congenital dislocation of the hip of 12 years' duration with chronic disability from pain led to retardation of growth from all growth cartilages of the affected limb in 1 case. In such instances dysplasia of the proximal femoral growth cartilages associated with the disturbed development of acetabulum and capital epiphysis may be a contributing factor to the shortening. Congenital hypoplasia and a short cavus foot resulted in marked shortening of the limb and conspicuous limp in another instance. Dyschondroplasia with involvement of one leg was accompanied by retarded growth and premature ossification of growth cartilages in a third case.

Tuberculous arthritis of the hip with extensive destruction of acetabulum and capital epiphysis caused shortening in 6 cases. Similar destruction of the joint from severe pyogenic arthritis accounted for shortening in 3 cases. In 2 patients with tuberculous arthritis and 1 with pyogenic infection of the hip prolonged disability led to severe retardation of growth from all epiphyses of the affected limb. In the latter case premature ossification of the medial part of the upper tibial growth cartilage led to a tibia vara deformity before growth was complete. In such cases eccentric or central ossification of the cartilage leads to localized bone bridging between epiphysis and metaphysis as demonstrated by Gill and Ross. Eccentric bony bridging produces angulation deformity when subsequent weight bearing stimulates growth from remaining cartilage. The resulting angulation deformity further contributes to the shortening.

Osteomyelitis of the shaft of the femur with prolonged disability led to retarded growth from all growth cartilages of the affected limb and premature ossification of the upper tibial growth cartilage in 1 case in this series.

Residual paralysis following poliomyelitis was responsible for retarded growth of the leg in the remaining 2 cases. Reduced functional stimulation or nutritional disturbances associated with altered blood flow through the extremity may account for such inhibition of longitudinal growth in paralyzed limbs.

### OPERATIVE TECHNIQUE

The history of leg shortening operations has recently been reviewed by White, Howorth, and Phalen and Chatterton making repetition unnecessary.

The technique of resection and fixation of the apposed bone ends with an intramedullary peg fashioned from the resected bone has previously been employed by Taylor, Calvé, Royle, Ritter, Groves, Moore, Camera, Harmon and Krigsten, and Howorth. The method used here is similar in principle and differs only in location of the sight of resection.

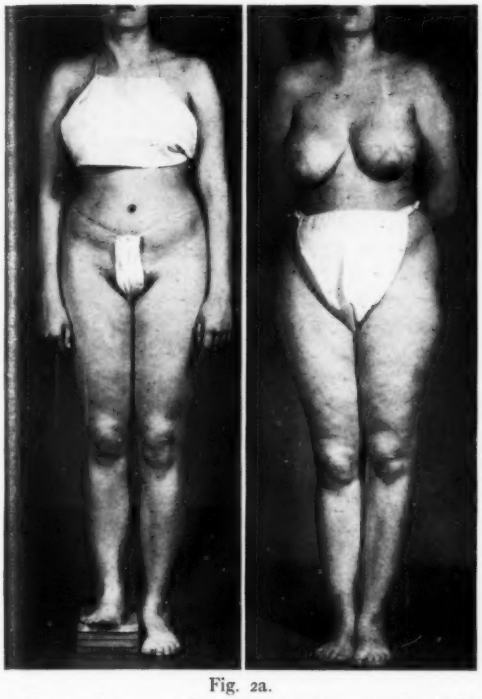


Fig. 2a.

Fig. 2. Case 1. a, The patient before operation (left) and 2 years and 5 months after shortening the left femur 2 inches (right). b, Distal end of the left femur 8 weeks after the shortening operation. The onlay grafts have united and ossified callus bridges the bone ends. c, Distal end of the left femur 2 years and 5 months after the shortening operation.

A bloodless field is obtained by application of an Esmarch bandage high on the thigh. Through a 7 inch lateral incision over the distal end of the femur the fascia lata is incised and the vastus lateralis muscle identified. The muscle is reflected anteriorly from the intermuscular septum.

The lowermost anterior perforating branches of the profunda femoris artery and vein are identified, ligated, and cut. The periosteum is incised longitudinally and elevated from the circumference of the metaphysis over the segment to be excised. The segment of bone to be removed is marked with a chisel and the distal osteotomy is made first with a Gigli saw. The shaft of the femur may then be displaced outward and the proximal osteotomy with the Gigli saw facilitated.

Fig. 2b.

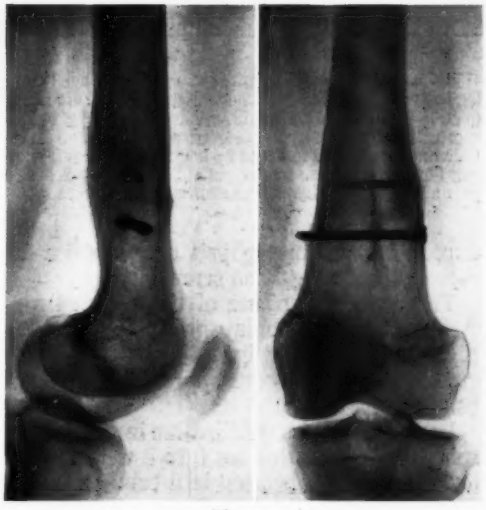
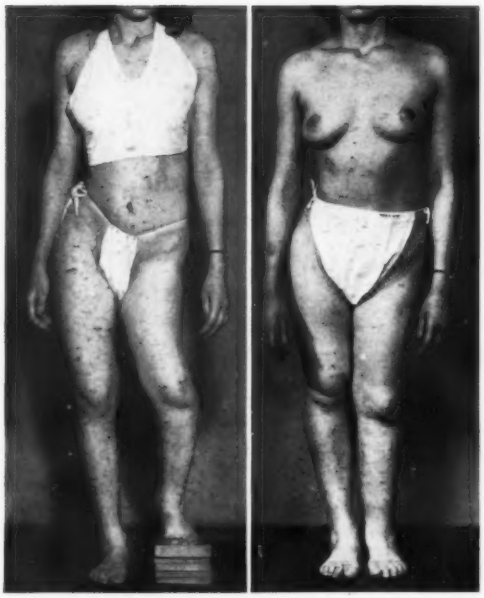


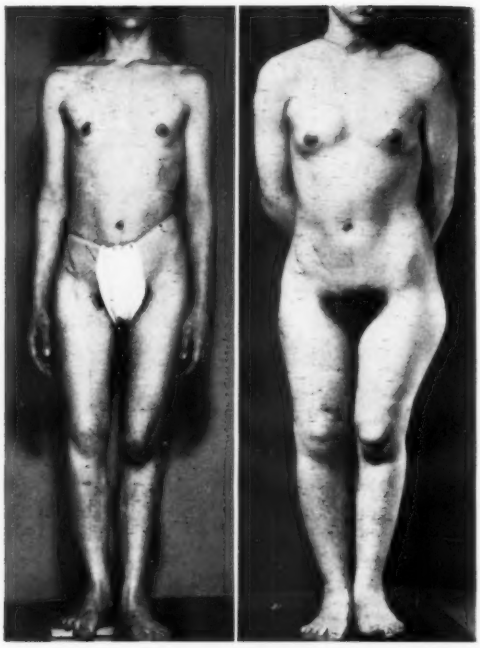
Fig. 2c.

The resected segment is divided longitudinally into several parts with the motor saw and one portion is used for the intramedullary graft. One-half of the graft is inserted into the proximal shaft. A hole is drilled through the outer cortex, graft, and inner cortex and a transfixion screw or threaded pin is inserted. The protruding half of the graft is then intro-



a b

Fig. 3. Case 2. a, The patient at 17 years of age before leg length equalization procedures were done. There is abduction deformity of the left hip, tibia vara, and 7½ inches shortening of the left leg. Osteotomies of the hip and upper tibia and fibula were followed by lengthening the left tibia and fibula 2¼ inches. b, The patient at 19 years of age, 1 year after the right femur was shortened 2¾ inches.



a b

Fig. 4. Case 3. a, The patient, 2 years and 7 months after derotation osteotomy and arthrodesis of the right hip for unreduced congenital dislocation (left). b, The appearance 6 months later after shortening the left femur 2¼ inches.

duced into the metaphysis and likewise secured with a transfixion screw.

The remaining pieces of the resected segment are used as onlay grafts as shown in Figure 1 and may be ligated in place with catgut. The soft parts are approximated in the usual manner.

Postoperative immobilization in a single hip spica plaster dressing for 6 to 8 weeks is followed by weight bearing in a tubular plaster dressing until bony union is complete.

Quadriceps exercises are encouraged during the period of immobilization and active knee exercises are continued after removal of the support.

## CASE REPORTS

Congenital hypoplasia associated with a short cavus foot was responsible for 2 inches of shortening of the right leg in the following case. Exact equalization of limb length was accomplished in this instance.

CASE 1 (Case No. 9, Table I). B. H., aged 14 years, had deformity of the right foot at birth and shortening of the limb was first noted at 2 years of age. Her father had similar deformity of the right foot but no shortening of the limb or disability.

Examination revealed 2 inches of shortening of the right leg. There was cavus deformity of the right foot which was smaller than the left. There was no impairment of sensation or motor power.

The length of the limbs was equalized by shortening the left femur 2 inches. Figure 2a shows the patient before operation and 2 years and 5 months after the femoral shortening operation. Figure 2b shows the roentgenographic appearance of the left femur 8 weeks after operation.

Figure 2c shows the result 2 years and 5 months later at 16 years of age. The length of the legs was equal at that time.

Prolonged disability from infectious arthritis of the hip at 4 years of age was followed by premature ossification of the lower femora,

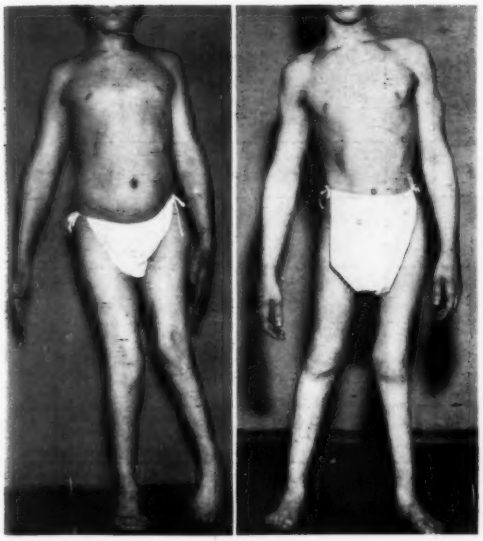


Fig. 5a.

Fig. 5. Case 4. a, The patient at 6 years of age with 2 centimeters shortening of the left leg (left). On the right the same patient at 15 years of age, 7 months after shortening the right femur 1½ inches. b, Distal end of the right femur 7½ weeks after operation. c, Distal end of the right femur 2 years and 6 months after the shortening operation.

upper and lower tibial growth cartilages in the following case. Marked retardation and early arrestment of growth from all growth cartilages including those destroyed by the hip disease produced 7½ inches relative shortening. Hip deformity and tibia vara accounted for part of the shortening. Complete equalization could not be accomplished in this instance because of marked length discrepancy and short stature of the patient.

Case 2 (Case No. 4, Table I). J. P., aged 17 years, had infectious arthritis of the left hip at 4 years of age. The limb was immobilized in a plaster hip spica dressing for 3 years during which drainage was present. A long leg brace was worn for an additional 7 years. Ankylosis of the joint occurred during the fifth year of the disease. Ten years after onset subtrochanteric osteotomy was done and the brace discarded. She was first seen at the University of Chicago Clinics 3 years later at 17 years of age. Examination showed ankylosis of the left hip in approximately 20 degrees of abduction and 30 degrees of flexion. There was varus deformity of the proximal end of the tibia with marked overgrowth and bowing of the fibula. The left limb was 7½ inches shorter than the right.

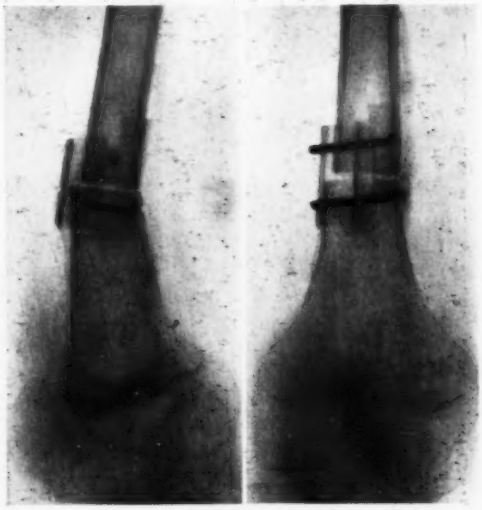


Fig. 5b.

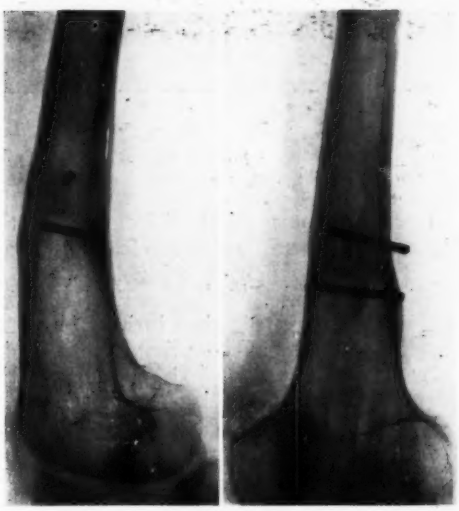
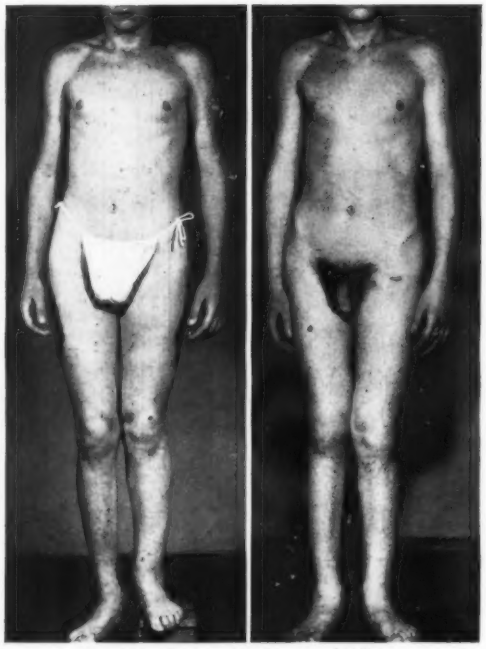


Fig. 5c.

Hip deformity and varus deformity of the tibia were corrected by osteotomies of the upper femur, tibia, and fibula. The left tibia and fibula were then lengthened 2¼ inches. Five months later the right femur was shortened 2¾ inches. Residual shortening of the left limb is approximately 1¾ inches. Figure 3a shows appearance of patient on admission. Figure 3b shows same patient 1 year after operation. Gait is good and she has no back disability from pelvic tilt 3½ years after last operation.



a b

Fig. 6. Case 5. a, Appearance of the patient at 14 years of age before operation. b, The patient 3 months after shortening the right femur 2¼ inches.

Unreduced congenital dislocation of the right hip with retarded growth from disuse accounted for marked shortening of the limb in the following case. After operative reduction and arthrodesis of the hip 3 inches of residual shortening of the affected limb was partially corrected by resection of 2½ inches from the lower femoral metaphysis of the left femur.

CASE 3 (Case No. 5, Table I). H. M., aged 15 years, was first examined for untreated congenital dislocation of the right hip at 12 years of age. Shortening, limp, and pain in the right thigh after exercise had been noted since she first walked. Two older sisters had been treated for bilateral congenital dislocation of the hip.

Examination revealed shortening of approximately 4½ inches when standing. Approximately 2 inches could be accounted for by upward displacement of the femur. Trendelenburg's sign was positive and there was marked limp.

Two years and 7 months after derotation osteotomy and arthrodesis of the hip, there was 3 inches residual difference in leg length. The discrepancy was reduced to ¾ inch by resection of 2¼ inches from the left lower femoral metaphysis. Figure 4 shows the patient before the left femur was shortened and the appearance 6 months after resection of 2¼ inches from the left lower femoral metaphysis.

TABLE I.

| Case No. Name | Age—years, Sex | Disease | Leg length discrepancy, inches | Operative shortening, inches | Other corrective or palliative procedures |
|---|---|---|---|---|---|
| 1 F.K. | 18 F | Tuberculous arthritis r. hip | 2 | 2 | Arthrodesis. r hip<br>Complete epiphyseal arrest. left knee |
| 2 E.M. | 16 M | Pyogenic arthritis l. hip | 2 | 1½ | Sequestrectomy, l hip<br>Subtrochanteric osteotomy l femur |
| 3 E.K. | 14 M | Tuberculous arthritis l. hip | 1¾ | 1¾ | Arthrodesis, l. hip.<br>Subtrochanteric osteotomy l. femur |
| 4 J.P. | 18 F | Pyogenic arthritis l. hip | 7½ | 2¾ | Osteotomy, l. tibia & fibula.<br>Subtrochanteric osteotomy l. femur.<br>Leg lengthening, left. |
| 5 H.M. | 15 F | Congenital dislocation r. hip | 3 | 2¼ | Derotation osteotomy, r. femur.<br>Arthrodesis, r. hip |
| 6 N.W. | 12 F | Tuberculous arthritis r. hip | 3 | 2 | Arthrodesis, r. hip.<br>Subastragalar arthrodesis r.<br>Subtrochanteric osteotomy r. femur |
| 7 C.H. | 13 F | Tuberculous arthritis r. hip | 2 | 2 | Arthrodesis, r. hip.<br>Intertrochanteric osteotomy, r. femur |
| 8 S.M. | 14 M | Residual poliomyelitis trunk & limbs | 1½ | 1½ | Arthrodesis, l. hip.<br>Triple arthrodesis r. & l. |
| 9 B.H. | 14 F | Congenital hypoplasia r. leg | 2 | 2 | None |
| 10 L.M. | 17 F | Residual poliomyelitis r. trunk & leg | 2¼ | 1¾ | Triple arthrodesis, r.<br>Peroneal tendon transplantation, r. |
| 11 R.B. | 14 M | Dyschondroplasia | 3 | 2½ | None |
| 12 L.L. | 15 M | Tuberculous arthritis r. hip | 2½ | 2¼ | Arthrodesis, r. hip.<br>Osteotomy, r. tibia |
| 13 E.R. | 15 F | Pyogenic arthritis r. hip | 1¾ | 1¾ | Partial ostectomy, r. femur.<br>Sequestrectomy, r. hip |
| 14 M.J. | 17 F | Tuberculous arthritis r. hip | 2¾ | 2¼ | Arthrodesis, l. hip |
| 15 D.P. | 13 F | Osteomyelitis r. femur | 3 | 2 | Partial ostectomies, r. femur.<br>Excision, upper end r. fibula |

Severe residual paralysis of trunk and lower extremities following poliomyelitis at 21 months of age led to unequal growth of the lower extremities and length inequality of 1½ inches in the following case.

CASE 4 (Case No. 8, Table I). S. M., aged 14 years, had acute anterior poliomyelitis at 1 year and

9 months of age with severe residual paralysis of the trunk and lower extremities. At 6 years of age, caliper braces and a Hoke corset were provided. He was able to walk short distances with crutches but was severely disabled. Two centimeters of shortening of the left leg at 7 years of age increased to 3.5 centimeters in the following 6 years. Correction of this discrepancy by epiphyseal arrest was not believed indicated because of his limited ability to walk. At 13 years of age subluxation and instability of the left hip necessitated arthrodesis of the joint. This was followed by bilateral triple arthrodesis. These procedures were followed by marked improvement in gait. In the presence of weak trunk musculature and inability to elevate the right side of the pelvis it was believed that further improvement would follow equalization of the length of the legs. Accordingly the right femur was shortened 1½ inches. Figure 5a shows the patient at 6 years of age and at 14 years of age following arthrodesis of the left hip, stabilization of both feet, and shortening the right femur.

Figure 5b shows the roentgenographic appearance approximately 2 months after the shortening operation. Figure 5c shows the lower end of the femur 2 years and 6 months later. He walks well with one cane and is able to walk short distances without support.

Chondrodystrophy of the left femur and tibia in the following case resulted in premature ossification of the growth cartilages at the knee with 3 inches of shortening of the leg when growth was complete. Partial equalization of length was accomplished by resection of 2¼ inches from the distal metaphysis of the right femur.

CASE 5 (Case No. 11, Table I). R. B. was first observed at the age of 14 years. At 10 years of age it was first noted that the left leg was 1¾ inches shorter than the right. Roentgenographs revealed exostoses of the upper and lower femur, and at both ends of the tibia.

Examination on admission at The University of Chicago Clinics revealed 3 inches of shortening of the left leg with increase in the diameter of the tibia at both ends as seen in Figure 6a. He limped conspicuously. Hard bony masses were felt on the anteromedial aspect of the distal end of the tibia, and on the medial aspect of the distal end of the femur. Roentgenographs of the right knee showed narrowing of the shadows of the growth cartilages but the epiphyses were not united. Roentgenographs of the left upper tibia and lower femur showed a cartilaginous exostosis on the medial femoral metaphysis and four exostoses in the upper half of the tibia. The growth cartilages were ossified.

The right femur was shortened 2½ inches. Figure 6b shows the appearance of the patient 3 months after operation. One year after operation his gait and appearance were normal. There was no increase in the residual length discrepancy of ½ inch.

## DISCUSSION

Data from the 15 cases are compiled in Table I. Cases 1 to 12 have been observed for periods of 1½ to 9 years after operation. The remaining 3 patients have been operated on within 6 months and are under observation. The longest period of postoperative immobilization was 16½ weeks in 1 case. The average period of immobilization was 10 weeks. Weight bearing with support was begun 6 to 8 weeks after operation. Postoperative infection was not encountered. In 1 instance separation of the bone ends occurred due to splitting of the intramedullary graft. In this case drill holes had not been made prior to the introduction of the transfixion screw. Reoperation was necessary.

Permanent quadriceps weakness was not observed in any of these cases. Quadriceps power returned to normal soon after removal of the plaster dressing and the duration and degree of weakness was no greater than that observed following similar periods of immobilization for other operations or injuries.

Circumferential elevation of periosteum from compact cortical bone of long bone diaphyses is a significant factor in producing avascular necrosis of the bone ends in fractures or operations. Healing of such a fracture or osteotomy is accompanied by gradual absorption of necrotic cortex and its subsequent replacement by living bone. Bridging of the ends by ossification of intermediary callus may be delayed for 6 months or longer and unless immobilization is prolonged, incomplete ossification and nonunion may result. In the metaphysis where cortex is thinner and the blood supply is relatively greater, extensive necrosis is less apt to occur. Metaphyseal fractures generally heal rapidly, and experience with metaphyseal shortening of the femur reported here has shown that healing can be expected in approximately the time required for union of a fracture in the same location.

The lateral intermuscular approach to the distal end of the femur is simple and trauma to the quadriceps apparatus is minimal. Organization of hematomas and fibrosis of the vastus intermedius in midfemoral fractures and operations may leave permanent restric-

tion of flexion of the knee. Knee motion returned to normal 6 to 8 weeks after removal of the plaster dressing in all patients with metaphyseal shortening in this report.

Shortening the femur in the distal metaphysis minimizes the antagonistic action of hip and thigh musculature at the site of the osteotomy. The action of hip flexors and adductors may produce angulation in transverse diaphyseal osteotomies in the presence of both internal fixation and external immobilization with plaster. In osteotomies done above the condyles plaster immobilization is more effective and the adductor magnus and longus have relatively little effect on the osteotomy site. Tension of the gastrocnemius is reduced by immobilization of the knee in slight flexion.

Experience with these cases leads to the conclusion that supracondylar metaphyseal shortening of the femur is a relatively simple, safe method of equalizing leg length. Operative trauma is minimal and the period of postoperative immobilization is short.

## SUMMARY

1. The principles involved in leg length equalization procedures are discussed. Heredity, bone age, sex, stature, amount of length discrepancy, condition of the tissues of the shorter limb, and associated disability or deformity are the chief factors to be considered.

2. The causes of leg length inequality in 15 cases are enumerated.

3. A method of shortening the femur in the distal metaphysis is described.

4. Five illustrative cases and end-results in 15 cases of supracondylar shortening of the femur are presented.

5. Anatomical factors related to the choice of operative site in femoral shortening are discussed.

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# ANAL ILEOSTOMY WITH PRESERVATION OF THE SPHINCTER

## A Proposed Operation in Patients Requiring Total Colectomy for Benign Lesions

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THE operation of total colectomy is most often performed for one of two conditions—multiple polypoid adenomatosis of the colon, and chronic nonspecific ulcerative colitis.

Multiple polypoid adenomatosis of the colon, or multiple polyposis, has been well established to be a familial disease, beginning with the report of Cripps. While it can make its appearance, symptomatically, as early as the age of 2 years (11) it is more often diagnosed in the second and third decades (9).

The therapeutic approach to multiple polypoid adenomatosis limited to the colon must be governed by the known facts concerning the condition—specifically, the high incidence of malignancy developing in such polypoid adenomas, and the high mortality reported. Various authors report an incidence of proved malignancy, in such patients, of from 26 per cent (15) to 62.5 per cent (2), with 35 to 40 per cent (6) as the most frequently reported figure. In 127 collected cases (6), 76 treated medically had a mortality of 56.5 per cent and 51 cases treated by any surgical means had a mortality of 35.1 per cent. The youngest patient diagnosed as having cancer was 12 years (7), the youngest dying of cancer was 15 years (11). Lockhart-Mummery states that in all such patients cancer will develop if they survive. The usually recommended surgical treatment is resection of the involved bowel, which often means a total colectomy and permanent ileostomy. A number of authors recommend fulguration of polyps in the area accessible to a sigmoidoscope and resection of the remainder of the colon with ileosigmoidostomy. Lilienthal, Soper, Erdmann, Tom Jones (12), and Lockhart-Mummery all have reported successful cases by this method. Stone and Rankin have also had such cases. However, in a good number of such patients cancer has been reported to develop subsequently in the remaining rectal segment. We have had such an experience in this hospital.

From the Surgical Hunterian Laboratory of the Department of Surgery, The Johns Hopkins University.

Presented before The Society of Clinical Surgery, Baltimore, Md., November, 1, 1946.

Since this report was submitted the procedure described has been applied to a patient with ulcerative colitis. The result, 3 months after operation, is encouraging.

### CASE REPORT

F. K., No. 100268, a white girl of 16 years, entered the Johns Hopkins Hospital September 29, 1936,

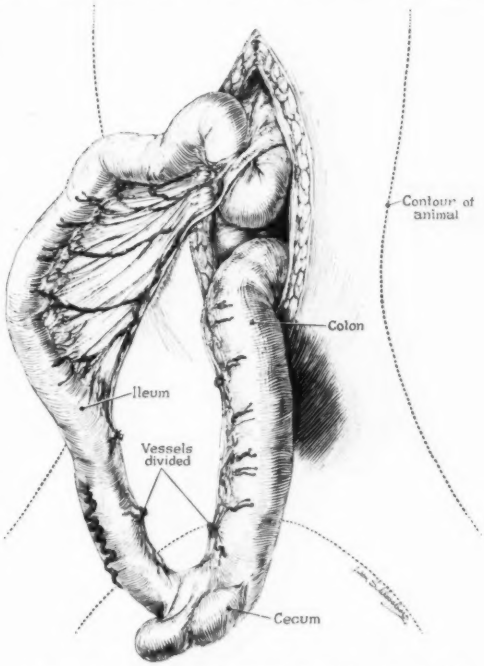


Fig. 1. Mesocolon and vessels ligated and divided. Terminal ileum mobilized by division of two arcuate vessels.

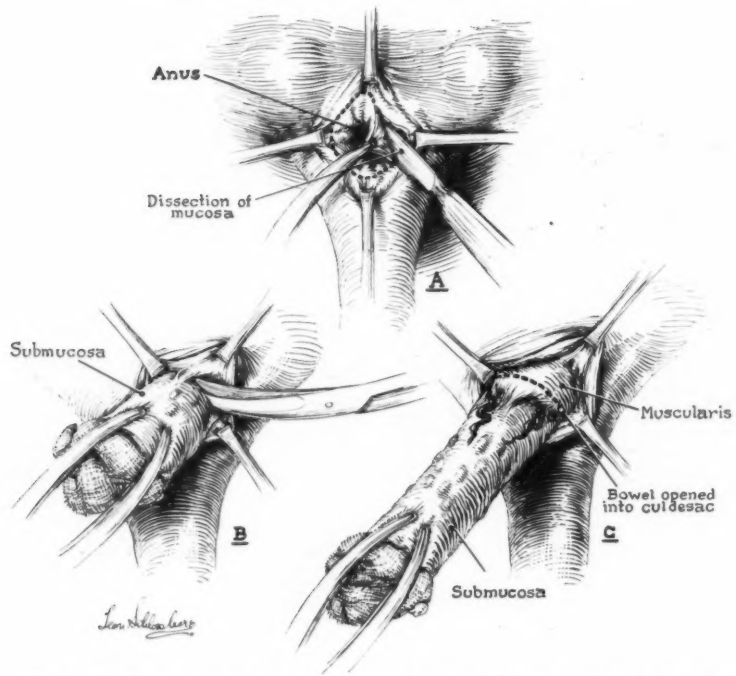


Fig. 2. A, Circular incision in mucocutaneous junction; B, gauze pack in rectum, submucosal dissection; C, dotted line indicates incision to be made through muscularis into peritoneal cavity.

complaining of abdominal cramps and diarrhea. Her father had died of cancer of the rectum at the age of 30. For 7 to 8 years she had bouts of diarrhea with cramps but without gross blood. She was admitted on the ninth day of a severe bout of diarrhea during the last 4 days of which generalized edema had developed.

Physical examination: She was extremely pale and generally edematous. There was clubbing of the fingers. Polyps were felt on digital rectal examination. The blood pressure was 120 systolic and 85 diastolic. The red blood cell count was 1,870,000, the hemoglobin 39 per cent. There were nucleated red blood cells in smears. The urine had a specific gravity of 1.010, albumin 70 grams per liter, and on microscopic examination there were 1 to 3 red blood cells and 1 to 3 white blood cells per high powered field. The stool was liquid and the guaiac test for blood was positive. Escherichia coli was recovered from the urine culture. The phenolsulfonphthalein excretion was 34 per cent in 2 hours, the urea clearance 25 per cent of normal. The nonprotein nitrogen was 76 milligrams per 100 cubic centimeters. Barium enema showed countless polyps in the entire length of the colon. Sigmoidoscopy showed innumerable small bleeding polyps of the entire rectum and lower sigmoid.

The urinary difficulties resolved on ammonium mandelate therapy. It was concluded that she had multiple polypoid adenomatosis with a coincident pyelonephritis. She was reported from this standpoint by Longcope and Whitehill.

Total colectomy was considered and abandoned in favor of preservation of the rectum and treatment of the distal segment with the cautery. A terminal ileostomy was performed December 1, 1936, and the colon subsequently resected in stages down to the rectosigmoid. All visible polyps were fulgurated proctoscopically on 9 occasions in November and December, 1937, until no more were seen. On December 31, 1937, an ileosigmoidostomy was performed after resection of 9 centimeters more of the sigmoid. This specimen contained numerous polyps. She was well thereafter, in the main, and able to work. Proctoscopy showed "questionable" sessile polyps on September 3, 1938, fourteen months after the last fulguration. Rectal examination on a number of subsequent admissions for pyelonephritis was negative. February 9, 1945, she returned obstructed by a carcinoma of the rectum. February 21, 1945, an abdom

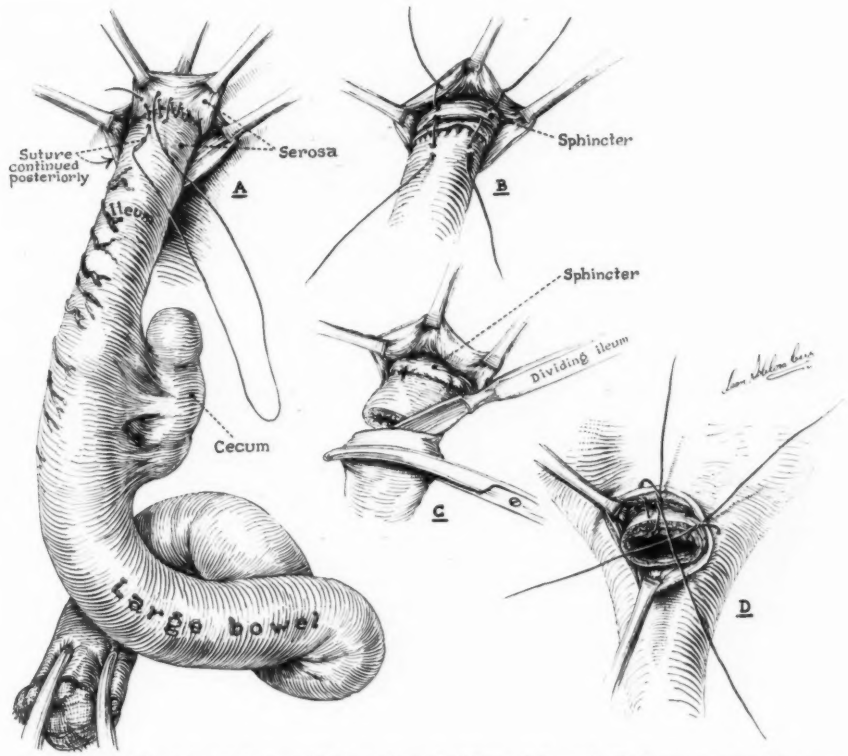


Fig. 3. A, Entire colon and several inches of terminal ileum delivered. Ileal serosa sutured to serosa of everted cuff of outer rectal coats remaining; B, external sphincter sutured to ileum with interrupted sutures; C, ileum transected; D, ileum tacked loosely to anal skin.

inoperineal resection with permanent ileostomy was performed. There was a large adenocarcinoma in the upper end of the rectum. The remainder of the rectal mucosa was covered by innumerable benign polyps.

She died October 18, 1945, in a convalescent home of progressive cachexia presumably due to metastases—8 years after her rectal fulgurations.

Examination of the gross specimen, with myriads of polyps carpeting the rectum, indicates the small likelihood that any considerable number of such cases will be cured if a segment of involved bowel is left behind for topical treatment. The disease is preponderantly familial, and a genetic predisposition to polyp formation should be expected to persist in this mucosa, however often it is fulgurated, with malignant degeneration constantly threatening as long as the patient lives.

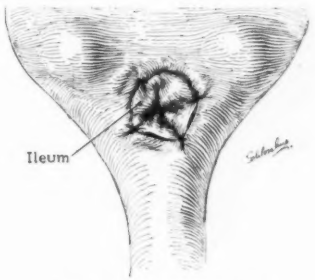


Fig. 4. Final appearance.

In short, multiple polypoid adenomatosis of the colon is a symptomatically troublesome condition with dangerous malignant potentialities. The only safe treatment is permanent eradication of the abnormal epithelium—that

Fig. 5. Barium enema of dog No. A20, 5 months after operation.

is, bowel resection. When the entire colon is involved, this means total colectomy. However, when operating in anticipation of but not in the presence of an established cancer, there is no need to remove the external sphincter.

Chronic, nonspecific ulcerative colitis is not fundamentally a surgical disease. Its treatment should be medical, and undoubtedly there will be found a basically sounder treatment than diversion of the fecal stream, and occasional subsequent extirpation operations. At present, however, it can be accepted that ileostomy is often life-saving, if undertaken sufficiently early (5, 17). That a certain percentage of patients will continue to have such troublesome symptoms after ileostomy, in large bowel diseased beyond any hope of restitution to a functional state, that colectomy will be required (1, 13). In these patients likewise, excepting those with multiple perineal and perianal fistulas, there is no need for sacrificing the sphincter ani.

In the experiments to be described the entire colon is resected, the sphincter preserved, and the ileum mobilized and sutured to the anus. The operation is offered for patients requiring total colectomy for nonmalignant conditions. From the standpoint of surgical therapeutic philosophy, this procedure has no relation to those designed to avoid colostomy in patients with cancer of the rectum and sigmoid.

### OPERATIVE TECHNIQUE

Under intravenous nembutal anesthesia, the vessels and mesentery of the colon are divided and the terminal ileum is mobilized in a manner analogous to that employed for mobilization of the jejunum in esophagoplasty—division of one or more arcuate vessels and the attached mesentery—until the ileum will reach the perineum (Fig. 1). The intestine is then replaced and the abdomen closed. In the dog it is impractical to attempt a reconstruction of the pelvic peritoneum. The anus and rectum are then cleaned and the anus packed with dry gauze to support the mucosa in the dissection. The anal margin is held with Allis clips and a circular incision made in the mucocutaneous junction (Fig. 2A). Dissection is carried up submucosally, the developing cylinder of mucosa and submucosa being clamped to the gauze sponge (Fig. 2B). With traction the bowel almost "peels" out. When a flap 5 or 6 centimeters long has been developed incision is carried through the outer rectal coats (Fig. 2C) into the peritoneal cavity. This frees the bowel which can be delivered through the intact sphincter. The entire colon and the mobilized ileum are delivered (Fig. 3A). The flap of outer coats of rectum is drawn down and everted so that it can be sutured to the ileum, serosa to serosa. A continuous suture of No. 0000 catgut is employed to seal off the peritoneal cavity. This is followed (Fig. 3B) by interrupted sutures of the same material tacking the sphincter to the bowel. The ileum is then transected (Fig. 3C) and loosely sutured to the anal margin (Fig. 3D) with interrupted silk.

The final result is surprisingly normal in appearance (Fig. 4). An observer accustomed to sigmoidoscoping dogs passed a sigmoidoscope on one of these animals 8 days after operation, reported no lesion, and did not suspect the

true state of affairs. The dogs vary in their reaction to the operation. Good sphincter tone is regained. Defecation is apparently voluntary and more or less deliberate. The stools change from liquid to soft as time passes, but the softness of the stools remains a problem which the dogs seem to solve by several small soft stools during the day and one copious stool at night. Dogs tolerate ileostomy poorly, and some of those surviving have shown considerable perianal excoriation during the weeks immediately following operation, gradually healing entirely. The x-ray film (Fig. 5), taken 5 months after operation, in a dog who was operated upon 6 months before the time of this report, shows no dilatation of the ileum.

The dogs were operated upon in two groups. Neither received parenteral fluids before or after operation and no attempt was made in either to replace the fluids lost through the ileostomy. In the first group no antibiotics of any kind were given. Of 22 dogs, 11 died of infection, usually pelvic abscesses and peritonitis. In the second series, the dogs received 0.5 gram of sulfasuxidine per kilogram per day for 4 days preceding operation (twice the usually calculated dose, but given in 4 doses per day rather than 6), and 300,000 units of penicillin in oil and beeswax an hour before operation, and another 300,000 units 24 hours later. None of the 6 dogs in the second group has shown any infection.

In man it may not be desirable to perform this operation regularly in one stage, particularly for ulcerative colitis. However, the feasibility of repairing the pelvic peritoneum and the possibility of pulling through a long stump of ileum to be divided later (we feared dogs would gnaw away such a stump) suggest to us that the operation should be safer in man than in the dog. We think that it may prove a feasible method of avoiding a permanent abdominal ileostomy in the patients requiring total colectomy for benign lesions.

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# TENDON TRANSFER OPERATION FOR IRREPARABLE PARALYSIS OF THE RADIAL NERVE

## Long Term Follow-up of Patients

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AMONG the reconstructive operations brought to the foreground by World War II are the various types of tendon transfers for paralysis of the radial nerve. Most surgical reports on this procedure date back to World War I and shortly thereafter; moreover there are few recorded follow-ups of more than a few months. The primary objective of this paper is to evaluate the results of tendon transfer operations for paralysis of the radial nerve as late as 26 years after operation.

Murphy in 1914 reported 2 cases of transfer of the flexor carpi radialis tendon to the extensor pollicis longus and extensors of the fingers for radial paralysis with excellent results. Murphy also indicated that he had done several operations of the same type previously. Byrne in June, 1916, reported attaching the flexor carpi radialis to the extensors of the thumb and fingers. The tendon transfer in this case was performed 2 years after destruction of the radial nerve and the result was "good." Credit for the operation was given to Murphy. Sir Robert Jones in May, 1916, wrote two excellent papers on tendon "transplantation" in which he discussed in detail operations for paralysis of the radial and median nerves. He indicated good results in 3 cases in which operation was performed by his associate McMurray. In the same year Henry described 1 case in which the flexor carpi radialis was pulled through the interosseous membrane and attached to the four finger extensors and the palmaris longus was inserted into the distal stump of the flexor carpi radialis. Weitz described methods and reported 2 cases. Schreiegg discussed technique in detail.

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Between 1919 and 1922 tendon transfer operations for irreparable paralysis of the radial nerve were described and cases reported by many investigators. McMurray and Jones were the chief advocates of the following type of operation: (1) pronator teres into the two extensores carpi radiales; (2) flexor carpi ulnaris into either all four extensors of the fingers or in McMurray's method to the ulnar three; and (3) flexor carpi radialis into the abductor pollicis longus, the extensor pollicis brevis and in McMurray's cases also to the extensor of the index finger (Fig. 1). Jones also inserted the palmaris longus into the extensor pollicis longus. In this country Billington introduced an operation essentially the same as that described by Jones. Pennell in 12 cases prevented ventral flexion of the wrist by means of a fascial graft from the third and fourth metacarpals to the radius. The flexor carpi radialis tendon was passed through the pronator quadratus or interosseous membrane to the extensors of the fingers. The palmaris longus was then inserted into the extensor pollicis brevis. Starr had 50 per cent of excellent results and only 1 failure in 52 cases in which the pronator teres was inserted into the extensor carpi radialis longus and extensor carpi radialis brevis, the flexor carpi radialis into the four finger extensors and the palmaris longus into the extensors and abductor longus of the thumb. Stevenson in 50 cases reported "good results" at 12 weeks in an operation similar to that of Jones.

Intervening years have yielded few articles on this subject except discussions of methods found in textbooks dealing with the hand (4, 10); however, in 4 cases with a maximal follow-up of 6 years good results were reported by Abbott in 1944 in an operation similar to that of McMurray along with arthrodesis of the wrist. Sudeck in 1943 described principles

to be observed. Recently Altman and Trott emphasized the value of numerous short incisions, including a 2 inch (5 cm.) transverse one on the dorsum of the wrist. In contrast to the right angle or U incision on the dorsum of the wrist, there was never slough. In 16 cases good results were obtained with usable grip in all. Dorsiflexion of the wrist was limited to approximately 25 degrees and extension of the fingers was incomplete by 15 degrees. The tendon transfer was similar to the Jones operation. The follow-up was brief, since most of the patients had been wounded in World War II.

Zachary in April, 1946, went into great detail concerning methods of quantitative measurement of results of tendon transfer operations for paralysis of the radial nerve. In the 57 cases of dorsal interosseous or radial nerve destruction exacting preoperative and postoperative studies of function were made. The paper should be studied by all future students in this field, since quantitative methods will aid greatly in arriving at a conclusion as to the best types of tendon transfers. In 24 cases the flexor carpi ulnaris and flexor carpi radialis were transferred to the thumb and fingers (Jones's type of operation). Very poor extension of the fingers resulted in 6 of these cases, in which there was no palmaris to help maintain some flexion at the wrist. Results in the other 18 cases with a palmaris longus present were somewhat better. In this series of 24 cases 50 per cent of ideal function based on degrees of motion and strength was calculated. In 29 instances the flexor carpi radialis was left intact and the flexor carpi ulnaris was passed to the finger extensors and in a few cases to the thumb extensors. In other instances the thumb extensors were activated by the brachioradialis, by the palmaris longus or by an active wrist extensor. Zachary expressed the opinion that transfer of the pronator teres to the radial wrist extensors is of value and has little effect on ability to pronate the forearm. His conclusions would indicate that function is incomplete unless the wrist retains one flexor muscle, finger extension being only 21 per cent in the one instance and 97 per cent in the other. Ability to flex the wrist to neutral position was 40 per cent versus 100 per cent

Extensor carpi radialis brevis m.
Extensor carpi radialis longus m.
Pronator teres m.
Flexor carpi radialis m.
Flexor carpi ulnaris m.
Extensors digitorum communis
Flexor carpi radialis m.
Abductor pollicis longus
Extensor pollicis brevis and longus

Fig. 1. Anatomy of tendon transfer operation of the Jones type with the exception that the palmaris longus is left intact rather than inserted into the extensor pollicis longus.

and range of thumb extension was 16.5 per cent versus 69 per cent. The over-all result was 50 ± 5 per cent versus 91 ± 0.4 per cent of ideal function. Each case is covered in detail in a chart.

## METHODS

Twenty-three patients who had destruction of the radial nerve and 5 who had loss of the dorsal interosseous nerve high in the forearm were studied. In all instances the site of injury of the nerve was explored and the nerve was found destroyed over a considerable distance or an anastomosis of the nerve ends was attempted with no sign of improvement for at least 1 year. All persons on whom the operation was performed through 1945 are included in the series despite complicating factors such as contractures and other nerve injury in some cases.

The follow-up consisted of a form letter in which the patient was asked to compare various functions of the injured extremity with the corresponding functions of the normal side in terms of excellent, good, fair, or poor. The general over-all impression of the patient was asked along with the specific degree of func-

Fig. 2. Complete radial paralysis. Result 10 months after Jones type of operation. Note extent of wrist motion and extension of thumb but slightly incomplete extension of fingers.

Fig. 3. a, above, Complete paralysis of the radial nerve, 1921; b, 6 weeks after operation with excellent extension of fingers, thumb, and wrist.

tion as related to the extent of wrist motion, finger extension, thumb extension, fist, and strength of grasp. In addition nearly all patients were seen and examined at least 2 months or longer after the original operation. Photographs and, in recent years, motion pictures were studied to aid in evaluating the results. In most instances in which all three methods of evaluation were used on one patient results agreed closely. Of necessity we are unable to evaluate our results in terms of degrees of motion or percentages because the personal examinations were done over a period of many years by many different observers. However, by studying photographs, impressions of the examining physicians and letters from the patients we have arrived at some valuable conclusions.

The tendons used and methods of transfer varied greatly. The Jones operation (Fig. 1) was performed in 10 cases, the McMurray type in 4, and the Jones type without transfer of the pronator teres in 5. The technique in the remaining 9 cases varied greatly. The cutaneous incisions in most cases were of the extensive type, including a J incision on the dorsum of the wrist. At the present time, however, small incisions at the sites of insertion of the flexor carpi ulnaris and the flexor carpi radialis, midway up the forearm over the body of each of these muscles and approximately in the midarm over the insertion of the pronator teres along with a somewhat longer incision just proximal to the dorsal carpal ligament are favored because of less tendency to scar and absence of necrosis of the skin.

## RESULTS

The over-all result (Figs. 2, 3, 4, and 5) for 28 cases was excellent in 10 cases, good in 13, fair in 5, and poor in none. When broken down into various operations the results were similar for each operation.

Six patients on whom operation had been performed between 11 and 26 years prior to their latest observation showed 3 excellent and 3 good results. This corresponded closely to the findings in those having transfers less than 1 year old; however patients on whom operation had been performed relatively recently were of course much less dexterous with their hands and fingers. In general it would appear that the ultimate outcome can be predicted by the findings a few months after operation.

The duration of complete muscular paralysis prior to operation varied from 2 months up to 23 years; in the latter case the result at 6 weeks was good. Strangely enough, the results were not related to the duration of paralysis.

Only 1 patient showed what appeared to be an incomplete ability to flex the fingers because of the transferred tendons being inserted too near the dorsal carpal ligament. Several others had incomplete flexion of the fingers when the wrist was flexed; however, from a practical standpoint fingers are rarely flexed with the wrist in ventral flexion.

Extension of the fingers was in all instances sufficient to permit normal function of the hand, although in many cases the little finger did not extend as completely as the other three. In most of the cases there was inability to extend the fingers completely with the wrist in neutral position, along with a tendency to extend the wrist somewhat on attempted complete extension of the fingers. This seemed to have little effect on the value of the hand and

Fig. 4. Same case as Figure 3. Twenty-six years after operation. The patient reported essentially normal function of her hand.

was less frequent in patients years after operation.

Although many types of tendon transfers were done to bring about extension of the thumb the degree of motion was universally sufficient to provide excellent function.

Wrist motion and grasp were satisfactory in most cases. Some of the patients are now doing manual labor and using their hands with no favoritism. Among the patients mention was made of ability to use the hand with ease when typewriting, playing the piano, golfing,

a b c

Fig. 5. a, Complete paralysis of the radial nerve, 1920; b, 16 months after operation extension is excellent; c, 16 months after operation patient is able to make a satisfactory fist. In 1946, 26 years after operation, he reported a satisfactory result.

welding, and so forth. One patient was on full duty in the armed services. In no instance did a patient regret having had the operation.

## CONCLUSIONS

Our series of 28 cases of irreparable destruction of the radial or dorsal interosseous nerve with a maximal period of follow-up of 26 years reveals that tendon transfer operations for radial paralysis are very successful as a rule. The exact type of operation in our cases seemed to make little difference; however, by using the quantitative measurements of results as recommended by Zachary the value of the individual types of operation can be more carefully ascertained in the future. We are inclined to feel that it is better to have the wrist extensors somewhat stronger than the flexors since slight extension of the wrist is necessary to produce a strong grasp, although there is no question but that the fingers will extend more completely in the presence of fairly strong wrist flexors. We recommend leaving the flexor carpi radialis intact provided the palmaris longus or some other active muscle is available for extension of the thumb. Arthodesis of the wrist was not done in any case and we feel that it is usually not necessary. Numerous short cutaneous incisions are preferred to extensive incisions with much undermining of cutaneous edges. As in all surgical procedures on the hand, good hemostasis and a minimum of trauma to tissue are essential. The flexor carpi ulnaris must be attached to the finger extensors sufficiently far from the dorsal carpal ligament to prevent impingement and fixation when flexing the fingers.

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# RADICAL AMPUTATIONS OF THE EXTREMITIES IN THE TREATMENT OF CANCER

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As our knowledge regarding the anatomic and clinical behavior of tumors of the soft somatic tissues increases and as our therapeutic experiences, radiologic as well as surgical, in the treatment of cancer of the limbs accumulate, certain definite concepts emerge. Throughout a period of twenty years there were over fifteen hundred cases of malignant tumors of the soft somatic tissues of the upper and lower extremities and the trunk, including over nine hundred cases of melanoma encountered on the Mixed Tumor Service of the Memorial Hospital. Perhaps the most significant realization garnered from this experience is that highly malignant connective tissue growths, melanomas, and selected cases of metastasizing epitheliomas must be dealt with radically *at the onset* if there is to be any hope for the patient's survival. It has been definitely proved that the prognosis becomes progressively poorer with an increasing number of recurrences following repeated local surgical excisions and conservative amputations, due to an obviously higher incidence of visceral metastasis.

Nowhere are these particular groups of cancers more favorably located for the application of radical surgical methods than on the limbs, especially when the regional lymph nodes have already been involved by the disease. Wide local excision of the primary tumor subsequently followed by a regional node dissection has proved to be an unsatisfactory surgical program in such a situation, for with this method the intervening lymphatic pathways are left intact. Only by "excision and dissection in continuity" can the primary lesion, intervening lymphatic pathways, and the involved regional nodes be entirely removed.

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*Excision and dissection in continuity* (4) is a term which we have employed to designate radical excision of the primary tumor, intervening lymphatics, and all regional lymph nodes by the same encompassing incisions. A wide removal of contiguous skin and even wider bloc of underlying fascia are included in the dissection. The surgical principle of excision and dissection in continuity is the same one on which the well established operations for breast and rectal cancer are based, namely, radical removal in continuity of the primary growth, intervening lymphatics, and the regional lymph nodes in one stage. If, however, the primary tumor is located too far from the first relay of lymph node metastasis (melanoma of the toe with metastasis to the inguinal lymph nodes), treatment by excision and dissection in continuity is not feasible. In such a case, only by exarticulation of the limb combined with excision of the regional lymph nodes can all gross limitations of the disease be widely removed—*interscapulothoracic amputation* (with or without supraclavicular neck dissection) for the upper extremity, and *hip joint disarticulation* (with or without deep iliac dissection) or *sacroiliac disarticulation* (*hemipelvectomy*) for the lower extremity, depending on the clinical and anatomic factors present in the given case. The indications, surgical technique, and end-results for all 3 of these radical amputations have previously been published by us (2, 5, 6).

The purpose of the present report is to analyze all of our cases of radical girdle amputations for malignant tumors in an effort to evaluate the usefulness of these operations for situations which have hitherto been considered practically hopeless. In addition, the value of radical amputation of the limbs in the palliative treatment of cancer will be discussed. This study is based upon 65 patients who were

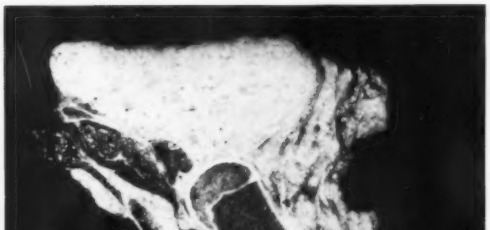

Fig. 1. Surgical specimen from an interscapulothoracic amputation. Bulky fibrosarcoma presenting as an axillary tumor in a 12 year old boy. Growth was densely adherent to posterior aspect of the scapula and head of humerus. This neoplasm could be removed only by a radical girdle amputation. Such low grade spindle cell sarcomas of the fascial-tendon-aponeurotic type are nonmetastasizing and the prognosis following *adequate* surgical removal is excellent.

Fig. 2. Melanoma of the skin of the shoulder. Large ulcerated, infiltrating melanoma with demonstrably involved lymph nodes (proved by aspiration biopsy) in the lower neck and axilla. Excision and dissection in continuity would not be feasible in this case. Nothing less than an interscapulothoracic amputation combined with a lower (supraclavicular) neck dissection should be elected in the presence of this anatomic distribution in order to remove completely the gross limitations of the disease *en bloc*. The prognosis following even such a radical surgical program is guarded in view of multiple node metastasis to more than one regional lymphatic basin.

subjected to one of the three major amputations, with or without a combined regional node dissection. All except 3 of these operations were performed on the Mixed Tumor Service of the Memorial Hospital from 1926 to 1946 without a single operative death.

### INTERSCAPULOTHORACIC AMPUTATION

Interscapulothoracic amputation is an operation devised to remove the entire upper extremity, scapula, clavicle, and their muscular attachments in one stage. The surgeon who performs such an extensive and mutilating procedure should have a clear conception of its indications and end-results, together with a comprehensive knowledge of the natural history of tumors.

*Indications.* The indications for this operation are malignant tumors of the upper limb which extend to, or through, the capsule of the shoulder joint or in its vicinity; extensive infiltrating cancers involving the deltoid, subscapular, and pectoral muscles, particularly the unencapsulated myosarcomas, neurogenic sarcomas, liposarcomas, synoviomas, fibrosarcomas, and spindle cell sarcomas of undetermined histogenesis; massive axillary neoplasms, especially where they have become adherent to major blood vessels, the brachial plexus, shoulder joint, scapula or clavicle; sarcomas of the scapula and clavicle where there is invasion of the axilla or shoulder joint (Fig. 1).

In the treatment of melanoma of the skin of the upper limb with demonstrable involvement of the axillary lymph nodes (proved by aspiration biopsy) and in anatomically similar tumors, interscapulothoracic amputation is indicated whenever the practice of excision and dissection in continuity cannot be technically carried out (Fig. 2). Thus the principle of exarticulation of the limb combined with excision of the regional lymph nodes is applied; in this way, the axilla is encompassed

and excised rather than entered and dissected, resulting in an *en masse* removal of the nodes, an obviously desirable method of eradicating a regional lymphatic basin which contains melanoma. In the event that the supraclavicular lymph nodes are also involved by tumor, a lower neck (supraclavicular) dissection can be included in the operation (Fig. 3).

This radical amputation occasionally has a definite place in palliative therapy. When an extensive cancer involving the upper limb and shoulder girdle has become ulcerated and infected with the production of uncontrollable, intractable pain, it might be prudent, in selected cases, to subject the patient to interscapulothoracic amputation even when distant metastasis has occurred. Elimination of sepsis and pain, conversion to ambulation and partial activity can be accomplished in certain hopelessly advanced cases only by radical amputation.

In our series of 25 cases, interscapulothoracic amputation was performed for melanoma in 6 cases; spindle cell sarcoma of undetermined histogenesis in 5 cases; neurogenic sarcoma in 3 cases; 2 cases each for rhabdomyosarcoma, fibrosarcoma, synovioma and lymphangiosarcoma; 1 case each for paraganglioma, myosarcoma and epidermoid carcinoma. Five of the operations, or 20 per cent, were performed for palliative purposes only. In 6 cases the procedure was combined with a lower (supraclavicular) neck dissection.

The oldest patient was 72 years and the youngest 10 years of age; the average age was 34 years.

*Operative considerations.* As previously mentioned, graphic illustrations of the operation and a description of our standardized technique were published in 1942 (2), at which time we stated that the anterior or pectoral approach of Kocher was preferable to the classical Berger operation.

After the middle third of the clavicle has been resected, the ligation of the subclavian vessels is postponed until the anterior incision is carried through the pectoral muscles into the axilla; this part of the dissection is similar to the same phase of a radical mastectomy, as the axillary artery and vein come immediately into view. With adequate exposure of the axilla and its contents, the subclavian vessels are more readily located and the underlying artery mobilized and ligated without the hazard of injury to the overlying vein. Ligation of the subclavian vein is delayed as long as is feasible to allow the limb to drain itself of as much blood as possible. Division of the pectoral muscles gives an excellent exposure of the brachial plexus, whose trunks are individually divided and ligated.

Fig. 3. Surgical specimen from an interscapulothoracic amputation combined with a lower (supraclavicular) neck dissection. Synovioma involving the flexor tendons of the wrist with metastasis to the lymph nodes of the axillary and supraclavicular spaces. The surgical principle of exarticulation of an extremity combined with excision of the regional lymph nodes is clearly indicated in this case. This type of tumor rivals that of melanoma in its malignant propensities. Operation performed under epidural anesthesia administered by one of us (F.C.G.). *P.T*, primary tumor; *M*, metastasis.

The linear incision over the clavicle is extended out to the acromion. The posterior flap is outlined by incising the skin along the vertebral border of the scapula, uniting it with the anterior axillary incision along the lateral axillary border. The muscles along the vertebral border of the scapula are transected, care being taken at this time to ligate the transverse cervical artery. The amputation is completed after the muscular attachments of the scapula have been severed. Most of the wounds are closed without drains.

*Complications.* Healing is unusually good in

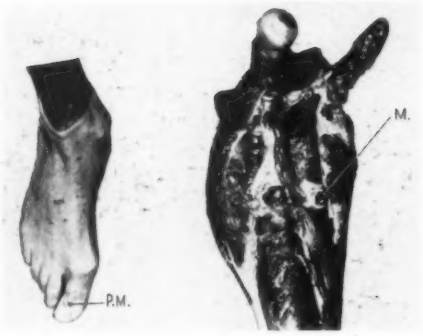


Fig. 4. Surgical specimen illustrating principle of exarticulation of an extremity combined with excision of involved regional lymph nodes. This patient, a 61 year old diabetic, developed a subungual melanoma (melanotic whitlow), the size of a match head, on the right great toe with bulky metastasis to the femoral trigone. The surgical principle of "excision and dissection in continuity" could not be utilized in this case because the first relay of lymph node metastasis was too far removed from the primary lesion. Thus, the only method whereby the primary tumor, intervening lymphatics, and involved regional lymph nodes could be removed in their entirety was by amputation through the hip joint combined with a deep iliac dissection. *P.M.*, primary melanoma; *M.*, Metastasis.

TABLE I.—INTERSCAPULOTHORACIC AMPUTATION FOR MALIGNANT TUMORS MEMORIAL HOSPITAL SERIES—MIXED TUMOR SERVICE—END-RESULTS 1926 TO 1946

| | | |
|---|---|---|
| Total number of cases | | 25 |
| Indeterminate group: | | |
| Total number of indeterminate results | | 1 |
| Dead as a result of other causes and without recurrence | 1 | |
| Lost track of without recurrence | 0 | |
| Determinate group: | | |
| Total number minus those of indeterminate group | | 1 |
| Failures: | | |
| Total number of failures in treatment | | 11 |
| Dead as a result of cancer | 11 | |
| Lost track of with disease (probably dead) | 0 | |
| Living with recurrence | 0 | |
| Successful results: | | |
| Free from disease at last examination | | 13 |
| End-results: | | |
| Successful results divided by determinate group (13/24) | | 54.2 per cent. |

these cases. Skin grafting is resorted to in instances in which the size and the location of the tumor and the degree of skin involvement require a greater sacrifice of skin.

Shock is rarely encountered and then is only minimal when proper sustaining measures, such as the use of blood during the operative procedure, are employed.

If a tumor is fixed, the pleural cavity might be entered with resultant pneumothorax, especially if the supraclavicular neck dissection is also carried out. This occurred in one of our cases; the pleural rent was repaired, the pneumothorax was appropriately aspirated, and the patient's convalescence was uneventful. Injury of the thoracic duct by a left interscapulothoracic amputation may conceivably occur, especially when combined with a lower neck dissection, although this complication was not encountered in the present series. Tributaries of the thoracic duct are ligated with fine wire or nylon and transected

*Prognosis following interscapulothoracic amputation.* The usefulness and limitations of this or, for that matter, any surgical procedure, can be determined accurately only by careful examination of all patients, if possible, at frequent intervals. Thus, valuable data with regard to the subsequent clinical course are accumulated, the analysis of which is of paramount prognostic import. End-results are reliable only when computed on such a basis. No patient was lost to follow-up examination in the present series of 25 interscapulothoracic amputations.

According to the histologic type of lesion for which this operation was employed, the prognosis was best for neurogenic sarcoma, fibrosarcoma, and spindle cell sarcoma of undetermined histogenesis, respectively. The least satisfactory results followed amputation for melanoma and synovioma. Other histologic types were encountered much too infrequently, usually singly, so that a discussion on prognosis regarding these would not be in order.

In about 75 per cent of our cases, the primary lesion on the limb was also associated with metastasis to the axilla (proved by aspiration biopsy) and of the remaining cases, the primary tumor was located either in the axilla, or in the supraclavicular or infraclavicular spaces. The anatomic site of the tumor, in those

patients operated on for curative purposes rather than for palliation, decidedly affected the eventual outcome, for whenever the primary growth was situated in or about the axilla or shoulder the prognosis was much more favorable. The tendency for nonmetastasizing sarcomas of the fascial-tendon type and of other low-grade (unclassified) spindle cell sarcomas to select the axillary and scapula regions so frequently explains the more favorable results which follow interscapulothoracic amputation for malignant tumors primarily located in the proximal end of the upper limb.

In radical amputation of the shoulder girdle whenever a supraclavicular or lower neck dissection was carried out during the same operative seance, the prognosis was not nearly as favorable as in the other clinical subgroups. Of 6 such cases, 4 were performed for melanoma and 1 each for synovioma and squamous carcinoma. Three of these patients died of visceral metastasis. It must be remembered, however, that 2 of these amputations were performed for palliative purposes only, which would ostensibly lower the net survival rate, particularly for the combined operation (plus neck dissection) on the upper limb, under discussion at the moment.

Interscapulothoracic amputation has a definite, although limited, use in the palliative therapy of cancer. In the present series of 25 cases, 5 were knowingly performed for palliative purposes only and, of these, 2 patients survived one year or more. Elimination of sepsis and pain and conversion of a bedridden, frequently malodorous patient to comfort and ambulation may occasionally be accomplished by such radical surgical methods.

In addition to the histologic type of lesion, the anatomic site, the performance of a superimposed partial neck dissection, and the indication for operation, the last but perhaps the most important factor affecting the prognosis following interscapulothoracic amputation is the number of previous surgical procedures (local excision, conservative amputation, axillary dissection, scapulectomy) performed before radical operation is carried out. In 65 per cent of our cases, the patient had been subjected to at least one such surgical procedure in an attempt to eradicate the growth and 7 patients had undergone two or more operations before interscapulothoracic amputation was finally done. As can be seen in Table I, the prognosis following this operation grows progressively worse with an increasing number of local recurrences due to a proportionately greater incidence of multiple regional node involvement and visceral metastases. This was particularly striking for melanoma, synovioma, and highly malignant unclassified spindle cell sarcoma. Only when interscapulothoracic amputation will be utilized as *the initial treatment*, provided that the indication is clear, will the net survival rate following this operation be appreciably improved.

Fig. 5. Surgical specimen from hip joint disarticulation. Endothelioma of the femur in a 9 year old girl, treated with several courses of heavy irradiation elsewhere, with no regression of the tumor. On admission, the patient was bedridden and suffering from intractable pain because of the ulcerated septic condition of the limb. Hip joint disarticulation was elected, in spite of pulmonary metastasis, purely as a palliative measure. This patient lived for 5 years following radical amputation, enjoying comfort and ambulation.

*End-results.* In this reported series of 25 interscapulothoracic amputations for cancer, 13 patients were operated on during the past 4 years and in 5 cases the operation was performed as a palliative measure. Of the 20 curative operations, 60 per cent of the patients

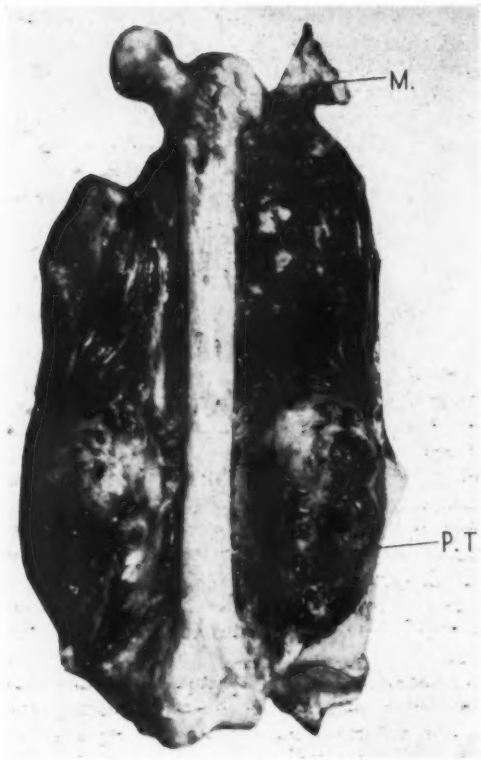


Fig. 6. Spindle cell sarcoma of the thigh with metastasis to the inguinal lymph nodes. Bisected surgical specimen from a hip joint disarticulation combined with a deep iliac dissection to illustrate the surgical principle of exarticulation of an extremity and excision of involved regional lymph nodes in one stage for the treatment of tumors other than melanoma. *P.T.*, primary tumor; *M.*, metastasis.

were alive at the time of the analysis without evidence of recurrence or metastasis. The over-all survival rate for the entire series is 54.2 per cent (Table I). The 5 year survival rate, based on 11 cases in which patients were operated upon prior to June, 1941, is 45.5 per cent.

### HIP JOINT DISARTICULATION

As with cancers of the upper limb, the management of malignant tumors of the lower extremity often entails amputation, and of the various surgical techniques employed, hip joint disarticulation, in selected cases, combined with deep iliac dissection if necessary, gives promise of becoming most effective. The present discussion is based on a personal experience with 32 cases of amputations through the hip joint, in 12 of which an *en bloc* excision of the iliac lymph nodes was carried out during the same operative seance. The oldest patient was 72 years and the youngest 3 years of age; the average age was 39 years.

*Indications.* Large malignant tumors of the soft parts of the middle and upper thigh which cannot be completely removed by wide excision and for which a high thigh amputation cannot assure an adequate margin are best treated by hip joint disarticulation. For malignant melanoma of the skin of the lower limb where involved inguinal and femoral lymph nodes are far removed from the primary tumor, the principle of "excision and dissection in continuity" cannot be applied; under such circumstances hip joint disarticulation combined with deep iliac dissection will accomplish effective removal of the primary tumor, intervening lymphatics, and all surgically accessible lymph nodes (Figs. 4 and 6).

Malignant tumors of bone and periosteum which occur in the middle and upper femur and for which a high thigh amputation cannot assure an adequate margin should be treated by hip joint disarticulation. Endothelial myeloma in such a location should be similarly treated if exhaustive studies have demonstrated absence of disease elsewhere.

This operation has a definite place in the palliative treatment of selected cases of cancer of the lower extremity. When the lower limb is the seat of a bulky, ulcerated, infected, foul-smelling growth which involves the upper thigh (malignant lymphoma, Kaposi's multiple hemorrhagic sarcoma, primary malignant tumor with distant metastasis, metastatic carcinoma) and the patient's general condition has not deteriorated too much, amputation through the hip joint for palliation and comfort is occasionally justified (Fig. 5). If exarticulation of the hip joint is performed for either a primary operable malignant tumor or for palliative purposes only, it is requisite that the neoplastic process should not extend to, or through, the hip joint, otherwise nothing less than amputation through the sacroiliac joint (hemipelvectomy) will suffice.

In this series of 32 hip joint disarticulations, 8 were performed for spindle cell sarcoma of undetermined histogenesis; 7 for melanoma; 5 for neurogenic sarcoma; 4 for synovioma; 2 each for rhabdomyosarcoma, chondrosarcoma and endothelioma; 1 each for reticulum-cell sarcoma and osteogenic sarcoma. Two of the amputations were performed as a palliative measure.

*Preoperative considerations.* Precautions should be taken to prevent shock. The use of an Esmarch or elastic bandage wrapped around the limb to be amputated is invaluable in conserving circulating blood volume. It should be carefully applied several hours before the operation is done. An elastic bandage is definitely contraindicated, however, in cases of melanoma where it might possibly aid in the dissemination of tumor cells into the blood stream. Constant administration of whole blood during the operative procedure is, of course, an essential feature in the prevention of shock which may occur following massive or uncontrollable hemorrhage, although this was not once encountered in any of our cases.

In the event that the tumor is ulcerated and infected, daily local treatment, consisting of gentle débridement, cleansing, and antiseptic sprays and frequently applied wet dressings, and chemotherapy is of distinct value in reducing the septic condition of the limb.

A Foley urethral catheter is inserted into the urinary bladder before the patient is taken to the operating room.

*Operative considerations.* Our standardized technique has recently been graphically illustrated (5) and will not be repeated in detail.

An anterior racquet incision is used. The neuromuscular bundle in Scarpa's triangle is cleared, and the femoral artery is ligated and divided (*above the profunda femoris*), as is the femoral nerve. Thick skin flaps are developed, after which all anterior muscle groups are transected as near to their insertion as possible. It is advisable to cut the sartorius and rectus femoris rather low so that they may be later used to cover the acetabulum. The femoral vein is then ligated and divided, thus completing the anterior dissection.

Adduction and internal rotation of the limb bring the greater trochanter into view so that the muscles which insert into it may be severed, after which the muscles of the gluteal group are cut. The capsule of the hip joint is incised and by further vigorous adduction of the limb the head of the femur is actually forced out of its acetabulum (surgical dislocation). After cutting the round ligament, the specimen is left attached to the patient only by a posterior pedicle consisting of the hamstring muscles and sciatic nerves, which are severed, thus completing the disarticulation.

### HIP JOINT DISARTICULATION WITH DEEP ILIAC DISSECTION

Whenever there is an indication to combine deep iliac dissection, for the purpose of removing iliac and retroperitoneal lymph nodes, with disarticulation of the hip joint, the technique must necessarily be modified. The method of radical groin dissection, as performed on the Mixed Tumor Service of the Memorial Hospital (3), is employed but is altered by omitting the dissection of the upper thigh and Hunter's canal. The apex of the incision is placed somewhat higher and more medially on the anterior abdominal wall and thin anterior and medial skin flaps are developed. Dissection is carried from above downward denuding the lower anterior abdominal wall, inguinal region, and femoral vessels of fascia, fat and lymphatic tissue *en bloc*. By splitting the inguinal ligament and retracting the peritoneum and urinary bladder, the retroperitoneal space is exposed widely. The chain of lymph nodes and areolar tissue along the iliac vessels are removed *en masse*, including those overlying the obturator foramen. If necessary, the anterior abdominal wall may be incised vertically upward, exposing the retroperitoneal space and its contents well beyond the aortic bifurcation. On completion of this deep iliac dissection the common femoral artery is ligated and divided *above the profunda femoris* and the operation of hip joint disarticulation is carried out in the usual manner.

The wound should be appropriately drained. Because of the extensive skin flaps which are developed when a regional node dissection accompanies the amputation, it is essential that a bulky pressure dressing be applied, firm enough to prevent pocketing of serum but not

TABLE II.—HIP JOINT DISARTICULATION FOR MALIGNANT TUMORS MEMORIAL HOSPITAL SERIES—MIXED TUMOR SERVICE—END-RESULTS 1926 TO 1946

| | | |
|---|---|---|
| Total number of cases | | 32 |
| Indeterminate group: | | |
| Total number of indeterminate results | | 1 |
| Dead as a result of other causes and without recurrence | 1 | |
| Lost track of without recurrence | 0 | |
| Determinate group: | | |
| Total number of minus those of indeterminate group | | 31 |
| Failures: | | |
| Total number of failures in treatment | | 19 |
| Dead as a result of cancer | 15 | |
| Lost track of with disease (probably dead) | 2 | |
| Living with recurrence | 2 | |
| Successful results: | | |
| Free from disease at last examination | | 12 |
| End-results: | | |
| Successful results divided by determinate group (12/31) | | 38.7 per cent |

too firm, otherwise necrosis of the flaps will occur.

*Complications.* In general, the course following hip joint disarticulation is relatively smooth and uneventful. When not combined with deep iliac dissection, the wound heals *per primam.* The utilization of extensive skin flaps, when the amputation is combined with deep iliac dissection, invariably produces skin necrosis along the wound margins, frequently resulting in infections. Lymphorrhea and pocketing of serum beneath the flaps also encourage infections and contribute to poor wound healing.

Aspiration of accumulated serum, judiciously applied pressure dressings, adequate postoperative penicillin therapy, and wide excision of irradiated skin are essential features in the prevention of infection and promotion of satisfactory wound healing following the combined operation.

*Prosthesis.* Because of the absence of a stump, the fitting of a prosthesis is a difficult matter following amputation through the hip joint, although additional iliac dissection does not add materially to this problem. We have employed a prosthesis for these cases consisting of a leather pelvic support to which the artificial limb is attached; this prosthesis has a double joint action and weighs 10 pounds (5). It is worn no more than 1 or 2 hours daily for the first few months as the patients find it quite tiring.

*Prognosis following amputation through the hip joint.* As pointed out in discussing the radical operation on the upper extremity, the prognosis following amputation through the hip joint will depend upon the anatomic type of tumor and its extent, the presence of visceral metastasis, and the number and variety of previous surgical procedures (local excision, local excision followed by groin dissection, conservative amputation). In general, the prognosis following hip joint disarticulation is about the same as that following interscapulothoracic amputation. In retrospect, however, in view of our past experience with radical amputations, 5 of the patients subjected to amputation through the hip joint (2 for palliation) would at present be treated by hemipelvectomy. A clearer definition of the indications for *disarticulation levels* will eventually improve the cure rate for both operations.

The most favorable results followed operation for neurogenic sarcoma and low grade (unclassified) spindle cell sarcoma. The least favorable outcome was encountered in melanoma and synovioma. Again, the majority of our patients were not ideally operable cases because of bulky metastasis to the inguinal lymph nodes with prior attempts at groin dissection. A more important factor to influence unfavorably the prognosis following radical amputation of the lower extremity is a high incidence of repeated, usually inadequate, surgical interventions, followed by recurrences, before disarticulation was finally done. Over four-fifths of the patients in the present series were subjected to some type of surgical procedure prior to radical amputation. In 21 cases, local surgical excision was performed at least once and in 10 cases 2 or more limited excisions had been performed. Three patients had undergone previous conservative amputation and in 4 cases groin dissection had been carried out. Only when radical amputation (disarticulation) will be employed

as *the initial mode of therapy in previously untreated cases*, provided the indication is clear, will we be able accurately and finally to evaluate the usefulness and limitations of such surgical practice in the management of selected cases of cancer of the extremities.

*End-results.* In the Memorial Hospital Series (Mixed Tumor Service) of 32 cases of hip joint disarticulation, 4 were performed for palliative purposes only. Of the 28 curative operations, 42.9 per cent of these patients are alive, as of June, 1946, with no evidence of recurrence or metastasis. Only 1 patient in this series of 32 cases was lost to periodic observation, after a follow-up interval of 2 years.

Almost three-fourths of the patients in this group were operated on during the past 4 years. The over-all net survival rate is 38.7 per cent (Table II). The 5 year survival rate is 33.3 per cent.

### SACROILIAC DISARTICULATION (HEMIPELVECTOMY)

Since 1944, we have performed the operation of sacroiliac disarticulation[1], in which the entire lower extremity, corresponding buttock, and innominate bone are removed in one stage, on 8 occasions. One of these operations was performed by the senior author at another hospital. The standardized technique as employed by us has been illustrated elsewhere(6) and is based on our modification of the surgical procedure first performed by Hogarth Pringle in 1916. The fact that the first operation of this kind was undertaken so late in the history of the Mixed Tumor Service may be explained by the many years which have been required to exploit more conservative therapeutic procedures, radiologic as well as surgical, for the treatment of malignant tumors of the soft somatic tissues before resorting to an extensive deforming operation, in addition to our present more comprehensive knowledge concerning the clinical behavior of tumors of the soft parts.

*Indications.* Sacroiliac disarticulation is indicated for primary malignant osseous and periosteal tumors of the upper femur where the growth has extended to, or through, the hip joint and for similar neoplasms of the innominate bone. Primary bulky malignant tumors of the soft somatic tissues of the upper thigh (involving the hip joint or extending through the obturator foramen), groin, buttock, pelvic parietes, and iliac region are best treated by amputation through the sacroiliac joint (Fig. 7).

Fig. 7. Surgical specimen from amputation through the sacroiliac joint (hemipelvectomy). Massive myxoliposarcoma (specimen bisected) involving the upper thigh and groin and extending over the anterior superior iliac spine. Dissection of the hindquarter revealed the tumor to be centered in the iliopsoas muscle. Bulky malignant infiltrating tumors of the pelvic parietes are occasionally amenable to surgical extirpation by disarticulation of the innominate bone.

Massive osteochondromas of the innominate bone and massive plexiform neurofibromas involving the upper thigh, groin, and hip joint or the buttock and pelvic parietes are best treated by exarticulation of the lower limb through the sacroiliac joint, if the tumors contain atypical areas histologically and if they cannot be adequately removed by wide local excision or some other type of conservative operation.

This radical operation occasionally has a definite place in the palliative therapy of cancer. Even in the presence of hopeless extension or distant metastasis, fungating, ulcerated tumors of the upper thigh, groin, and buttock may be removed in selected cases by sacroiliac disarticulation with gratifying results, provided the patient's general condition has not deteriorated too much.

The operations which are here reported

[1]Other terms which have been employed for this operation are hemipelvectomy, disarticulation of the innominate bone, hindquarter operation, interpelviabdominal amputation, interiliosacropubic amputation, transiliac amputation, and interinnominoabdominal amputation.

TABLE III.—SACROILIAC DISARTICULATION (HEMIPELVECTOMY) FOR MALIGNANT TUMORS MEMORIAL HOSPITAL SERIES—MIXED TUMOR SERVICE—END-RESULTS 1944 TO 1946

| | | |
|---|---|---|
| Total number of cases | | 8 |
| Indeterminate group: | | |
| Total number of indeterminate results | | 1 |
| Dead as a result of other causes and without recurrence | 1 | |
| Lost track of without recurrence | 0 | |
| Determinate group: | | |
| Total number minus those of indeterminate group | | 7 |
| Failures: | | |
| Total number of failures in treatment | | 2 |
| Dead as a result of cancer | 2 | |
| Lost track of with disease (probably dead) | 0 | |
| Living with recurrence | 0 | |
| Successful results: | | |
| Free from disease at last examination | | 5 |
| End-results: | | |
| Successful results divided by determinate group (5/7) | | 71.4 per cent. |

were performed for chondrosarcoma (2 cases), myxoliposarcoma (2 cases), neurogenic sarcoma, Kaposi's multiple hemorrhagic sarcoma, periosteal fibrosarcoma, and extraosseous osteogenic sarcoma. Two operations were performed for palliation. It is, of course, mandatory that a histologic diagnosis be established by aspiration or incisional biopsy before radical amputation or any other surgical, or nonsurgical program, for that matter, is planned.

*Operative considerations.* The preoperative considerations and precautions which were discussed for hip joint disarticulation are also applicable for cases of sacroiliac disarticulation. Inhalation anesthesia was employed for all cases. In any surgical procedure where a marked drop in blood pressure might occur, spinal anesthesia should not be elected. Rotation of the patient, which is necessary for the posterior dissection, definitely interferes with the technique of continuous spinal anesthesia. In addition, the psychic trauma necessarily induced by a mutilating operation is obviously lessened with the patient asleep.

As already mentioned, a detailed description of all steps of this operation as performed by us has been published elsewhere (6) and will not be repeated in the present report. Certain salient features of the technique, however, will be reviewed.

1. An anterior racquet incision is employed.

2. In the first few cases, we divided and ligated the external iliac artery as early in the operation as possible, but ligation of the vein was delayed to allow the extremity to drain itself of as much blood as possible. We soon found that ligation of the common iliac artery permitted a relatively bloodless operation. In one instance, however, necrosis of the posterior flap followed ligation of the common iliac artery, but this complication can be prevented by using a T incision with the straight crossbar along the inguinal region and the vertical incision resulting from a wide V excision of the center segment of the longer posterior flap.

3. By severing the pubic insertion of the rectus abdominis and dividing the inguinal ligament, the anterior abdominal wall is actually detached from the bony pelvis.

4. By retracting the peritoneum, its contents, and the urinary bladder, the iliac fossa is widely exposed. The ureter, peritoneum, intestines and urinary bladder must not be injured. The spermatic cord is preserved.

5. The symphysis pubis is easily divided with a Gigli saw but it should be clearly skeletonized, otherwise the pubic arch will instead be cut through.

6. The external iliac vein is ligated and divided just prior to exposure of the sacroiliac joint. Disarticulation of the joint is performed during the *anterior phase* of the dissection, using a chisel.

7. The posterior dissection is left for last, at which time the amputation is completed by severing the gluteal muscles, major ligaments of the sacrum, and the great nerve trunks of the lumbar and sacral plexus.

With this technique, all the major maneuvers of the operation are performed through an anterior approach, providing for ample exposure and easy access to vital structures in the pelvis.

*Postoperative complications: Abdominal distention* is a frequent postoperative complication. If a Levine tube is placed in the stomach as soon as the patient has reacted from the anesthetic and constant suction is applied for

48 to 72 hours, serious abdominal distention can be avoided. Obviously, large amounts of plasma should be given during this time to combat an inevitable electrolyte imbalance and hypoproteinemia.

*Paresis of the urinary bladder* occurs often but is only temporary, lasting 4 to 7 days. Continuous tidal bladder drainage is not only beneficial for an atonic bladder, but prevents soilage of the dressing during the first postoperative week.

*Anemia* is a constant postoperative manifestation and does not respond to iron, liver extract, or blood transfusions. We have found evidence, in our cases, of compensatory marrow hyperplasia. It is not unlikely, therefore, that removal of an entire lower extremity and innominate bone deprives the hemopoietic system of sufficient bone marrow so as to produce this normocytic normochromic anemia, which is only temporary, lasting about 3 weeks.

Fecal incontinence and abdominal herniation do not occur following this operation, although loss of libido is experienced rather frequently.

A prosthesis has never been devised for these cases. The patients learn to sit on the opposite ischial tuberosity and manage to use crutches satisfactorily after about 3 weeks of practice.

One of our patients, a 26 year old white female who was subjected to hemipelvectomy in March, 1945, for a neurogenic sarcoma of the thigh and pelvic parietes, married and became pregnant 1 year after operation and expects to give birth within a few months. No obstetrical difficulties should be anticipated in hemipelvectomized women; Judin's patient conceived and gave birth spontaneously to a healthy infant following sacroiliac disarticulation.

*Prognosis and end-results following hemipelvectomy.* The neoplasms of the soft parts which carry the best prognosis following this operation are neurogenic sarcoma and nonmetastasizing low grade spindle cell sarcoma of the fascial tendon type. Of the bone tumors, chondrosarcoma offers the most favorable prognosis.

In the present series of 8 sacroiliac disarticulations, 2 were performed for palliation; both of these patients died—one 12 months and the other 15 months after the operation. Of the 6 curative cases, 1 patient died suddenly 7 months after the operation, at which time there was no clinical evidence of recurrence or metastasis. The remaining 5 patients are alive and free from disease at the time of this analysis.

TABLE IV.—EXARTICULATION OF THE EXTREMITIES FOR MALIGNANT TUMORS MEMORIAL HOSPITAL SERIES—MIXED TUMOR SERVICE SUMMARY OF END-RESULTS 1926 TO 1946

| Type of operation | Number of cases | Over-all net survival rate per cent | Five year survival rate per cent |
|---|---|---|---|
| Interscapulothoracic amputation | 25 | 54.2 | 45.5 |
| Hip joint disarticulation | 32 | 38.7 | 33.3 |
| Sacroiliac disarticulation (Hemipelvectomy) | 8 | 71.4 | |
| Total number of cases | | 65 | |
| Over-all net survival rate | | 54.1 per cent. | |

The net survival rate for the entire series of hemipelvectomy patients in all stages of disease was 71.4 per cent (Table III). Obviously the 5 year cure rate cannot as yet be computed for this group as the operation was not employed by us until the year 1944.

## SUMMARY AND CONCLUSIONS

Sixty-five patients were subjected to one of three major amputations (interscapulothoracic amputation, hip joint disarticulation, sacroiliac disarticulation) for neoplastic disease on or about the extremities. These operations need not be hazardous. There were no operative deaths in this series.

The indications, operative technique, and postoperative complications for these three surgical procedures are discussed with special emphasis on the prevention and treatment of complications specific for cases of amputation through the sacroiliac joint.

The surgical principle of exarticulation of an extremity with excision of the involved regional lymph nodes in one stage for selected cases of melanoma and clinically similar tumors is presented and illustrated by 6 cases of interscapulothoracic amputation combined with a lower (supraclavicular) neck dissection and 12 cases of hip joint disarticulation combined with a deep iliac dissection.

The value of these surgical procedures in the palliative therapy of cancer is shown. Nine of the amputations in the present series were performed for palliative purposes only.

Interscapulothoracic amputation and hip joint disarticulation serve a definite and distinctly useful rôle in the treatment of selected cases of cancer of the extremities. With regard to amputation through the sacroiliac joint (hemipelvectomy), our cases are too few and too recent as yet on which to base an accurate and final evaluation of the operation. The accumulated evidence indicates that sacroiliac disarticulation will prove to be a valuable surgical procedure in the treatment of extensive cancers of the lower limbs, groin, buttock, innominate bone and pelvic parietes.

In this series of 65 cases, only 1 was lost to follow-up examination 2 years after operation. The 5 year survival rate following interscapulothoracic amputation is 45.5 per cent, and for hip joint disarticulation, 33.3 per cent. The net survival rate for cases of sacroiliac disarticulation is 71.4 per cent (Table IV).

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# EXTENSIVE COMBINED THORACOLUMBAR SYMPATHECTOMY IN HYPERTENSION

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In many instances, prolonged lowering of the blood pressure occurs in well selected cases following extensive thoracolumbar sympathectomy. It has been my experience that the fall in blood pressure with the patient in the horizontal position does not depend entirely on the extensiveness of the sympathectomy. The postural effect on the blood pressure, however, depends on the completeness of denervation of the splanchnic area. Therefore, to obtain effects immediately, or for a period of 3 or 4 months, it is not necessary to deviate from the technique of either the supradiaphragmatic approach used by Peet or the subdiaphragmatic approach employed by Adson. Smithwick demonstrated to his satisfaction that extensive removal of the sympathetic nervous system was necessary to maintain a prolonged lowering of blood pressure. In 1938, he devised an operation permitting him to combine the supradiaphragmatic approach of Peet with the subdiaphragmatic operation of Adson by the removal of the twelfth rib and incising the diaphragm, thus allowing exposure for a more complete splanchnic denervation. Grimson, in 1941, described a technique for complete thoracic and partial to total lumbar sympathectomy.

In my experiences since 1934 with the surgical treatment of hypertension, the technique advised and so adequately demonstrated by Peet was first employed. Later, the subdiaphragmatic approach was used as advocated and devised by Craig and Adson. In 1938, the latter technique was combined with a unilateral nephro-omentopexy. Since 1940, by a gradual evolvement the thoracolumbar sympathectomy has become more and more extensive (5).

It has been shown by many investigators[1] that regeneration of the sympathetic nervous system is most difficult to retard. That this is true is illustrated by special tests on 2 patients whose drop in blood pressure was considered good for a period of 2 years following operation. The preoperative blood pressure levels and the complaints of severe headaches returned, however, after the 2 years had elapsed. These patients were subjected to further removal of the sympathetic nervous system, with good results. It has been my experience that if an immediate drop in blood pressure does not occur within a reasonable length of time following operation, more extensive removal of the sympathetic nervous system will not be beneficial. Therefore, subjecting hypertensive patients to more extensive sympathetic denervation is justified only in patients who have had relief of symptoms for 6 months or more, whose previous complaints then returned and the blood pressure became elevated.[2]

Since neither the mortality nor the morbidity is increased by the technique that is employed at the present time, the added assurance that a more complete denervation has been accomplished makes the procedure a justifiable one.

The operation is performed in two stages at approximately 10 day intervals. The position of the patient during operation is of the utmost importance in facilitating the procedure. A lateral semiprone position is used (Fig. 1) with the thoracic spine flexed forward to as great a degree as possible. Flexion aids in making the upper dorsal ganglia more accessible. Either a combination of high spinal anesthesia, reaching up to the fourth thoracic level, and a light intravenous pentothal anesthesia, or the combination of pentothal, curare, and nitrous oxide is used. It is absolutely necessary to have adequate oxygenation throughout the operation.

From the Department of Neurosurgery, The Lahey Clinic.

[1]Dr. Kurt Richter, of Johns Hopkins Hospital, has studied many of our patients at varying intervals after operation from the standpoint of skin resistance.

[2]Poppen, J. L. The surgical treatment of essential hypertension. (In press.)

Fig. 1. Photograph showing the lateral semiprone position of the patient and the site of previous incision.

The incision is made paravertebrally over the thickest portion of the long muscles of the back at the line of cleavage of the longissimus dorsi and iliocostalis dorsi muscles. It extends from the level of the seventh rib, curving very slightly anteriorly, to the distal portion of the twelfth rib (Fig. 2). The longissimus dorsi and iliocostalis dorsi muscles are separated over the medial portion of the eleventh rib as well as over the seventh or eighth rib. The seventh rib is removed if the dorsal spine cannot be flexed, as is the case in a few straight backed individuals. If the dorsal spine can be flexed readily, experience has demonstrated that the fourth dorsal ganglion can be removed more easily through the eighth than through the seventh rib. The medial portions of the eleventh and the seventh or eighth ribs are then removed for a distance of approximately 4 centimeters from the transverse process, care being taken that the rib is not removed farther laterally than the width of the iliocostalis and longissimus dorsi muscles so as to prevent deformity. Removal of as much of the rib vertebrally as possible allows more adequate exposure.

Considerable care should be taken to enter the proper line of cleavage between the parietal pleura and endothoracic fascia. When the line of cleavage has been established, it can be followed medially with a semisharp Hedblom periosteal elevator to the anterolateral border of the bodies of the vertebrae where the greater splanchnic nerve lies. The index finger may then be inserted into the space and the line of cleavage followed cephalad and caudad through the openings of the seventh or eighth and the eleventh ribs. Caution must be exercised at this point that the palmar surface of the index finger is kept firmly against the endothoracic fascia rather than against the parietal pleura as the line of cleavage is being followed to prevent rupture of the parietal pleura. It is needless to emphasize that opening of the pleura should be avoided if at all possible since a relatively quiet anatomical dissection is immediately transformed into a more difficult and somewhat noisy procedure if the pleura is opened. Even though considerable care has been used, the pleura has been opened in 5 per cent of operations. The mere opening of the pleura may not be disastrous or cause more than relatively minor difficulties at the time the operation is performed. If by chance a postoperative infection should take place, however, one must necessarily deal with an empyema. This certainly is adequate reason to avoid studiously opening the pleura. Anesthesia can be of great assistance in preventing injury to the pleura by the control of the depth and rate of the respirations.

After the pleura has been separated paravertebrally cephalad to the level of the fourth thoracic ganglion and caudad to the attach-

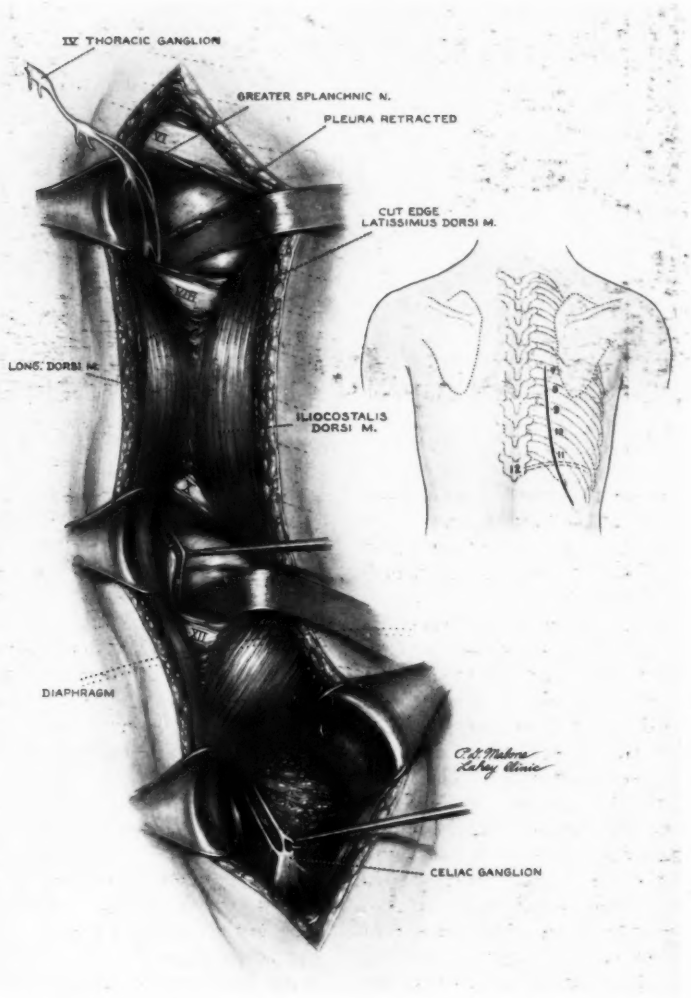


Fig. 2. The incision is outlined in the insert. The approach to the thoracic chain with its branches is made by removal of segments of the seventh or eighth and eleventh ribs by separating the iliocostalis and longissimus dorsi muscles. The long deep muscles of the back are retracted toward the spinous processes below the twelfth rib, thus allowing the retroperitoneal space to be entered by incising the transversalis fascia.

ment of the diaphragm, the greater splanchnic nerve is mobilized along its entire length. The greater splanchnic nerve is mobilized first because it is in a relatively avascular bed. With the patient in the semiprone position, if slight oozing should take place at the time the ganglia are mobilized and their respective rami divided, blood gravitates toward the mediastinum. If the greater splanchnic nerve were separated after the ganglia had been mobilized, possibly it would be obscured by blood-stained tissue.

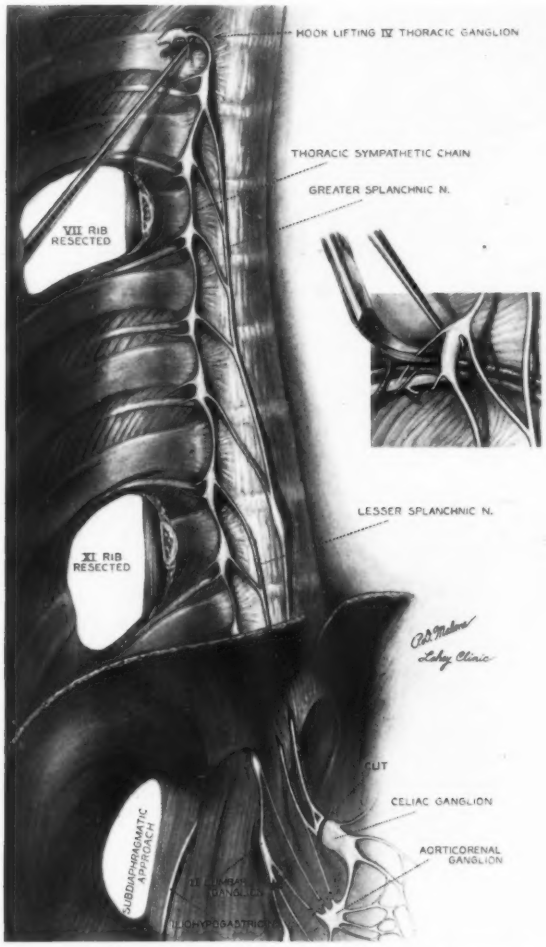


Fig. 3. The insert demonstrates the separation of the ganglion from the intercostal vessels before the rami communicantes are divided. The drawing allows visualization of the entire splanchnic distribution from the inside and its relationship to the apertures through which the removal is accomplished.

Great care is taken in mobilizing the delicate nerve fibers that make up the greater splanchnic nerve from the individual ganglia (Fig. 3). It is surprising to note the difference in the size of the individual ganglia as well as the fact that some of the ganglia do not have individual fibers leading from them to the greater splanchnic nerve (Fig. 4). In a few instances connecting fibers lead directly from the thoracic trunk to greater splanchnic nerve (Fig. 5*a*). The main trunk of the splanchnic nerve usually arises from fifth or sixth ganglion (Fig. 6), but in several patients it has arisen as a separate trunk from as high as the fourth ganglion (Fig. 7). The nerve itself may have one to several ganglia or may have none.

After the fourth thoracic ganglion has been mobilized, the trunk is divided above it. The

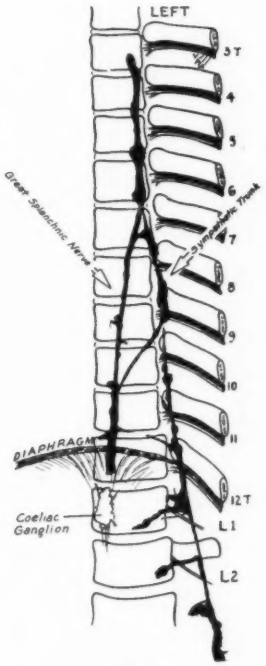


Fig. 4.

Fig. 5.

Fig. 6.

Fig. 4. Photograph of an actual specimen placed on a schematic drawing of the corresponding thoracic and lumbar vertebrae. Demonstrates the variation in the size of the ganglia as well as the fact that each ganglion may not have an individual connection with the greater splanchnic.

Fig. 5. Photographs of the actual surgical specimens showing the greater splanchnic arising from the thoracic ganglia by individual fibers. *a*, Demonstrates how two ganglia, in this instance the ninth and tenth, send joint fibers to the greater splanchnic as well as a separate branch from the thoracic trunk between them.

Fig. 6. Demonstrates the splanchnic arising from the fifth thoracic ganglion, *a*, and from the sixth thoracic ganglion, *b*.

entire mobilized upper sympathetic trunk and its branches are then pulled down through the aperture made by the removal of the eleventh rib, care being taken that the entire system is kept in continuity so that there can be no question or possibility of leaving any ganglia, or any fibers that lead to the thoracic aorta. Care must be taken that the thoracic ganglia are separated from the intercostal nerve and artery before dividing the rami to avoid unnecessary bleeding (Fig. 3, insert). All bleeding, even from a larger intercostal artery, can readily be controlled by the electrosurgical unit.

It has been my experience that the dissection is less difficult if the thoracic trunk is not divided until the desired number of ganglia that are to be removed have been mobilized.

After the thoracic ganglia and trunk, as well as the splanchnic nerve, have been completely mobilized in continuity to the diaphragm, the iliocostalis and longissimus dorsi muscles which are called the sacrospinalis muscle at the level of the twelfth rib, are retracted medially toward the spine. This permits the lumbodorsal fascia as well as the transversalis fascia to be incised, care being taken during the dissection that the iliohypogastric nerve is not injured. The retroperitoneal space is then entered and the soft tissues retracted anteriorly. The greater splanchnic nerve can be readily identified as it emerges through the diaphragm, usually through a hiatus of its own (Fig. 3), although it may emerge through the aortic hiatus. The greater and lesser

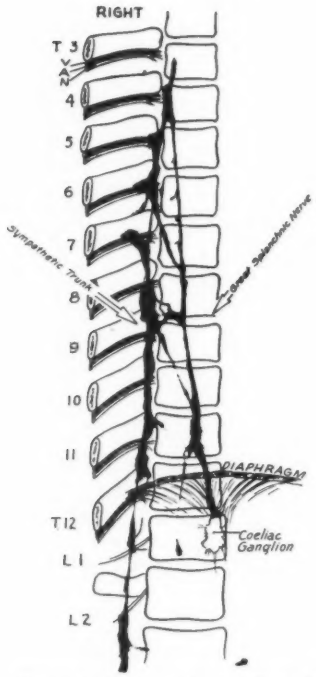


Fig. 7. Demonstrates separate ganglia in the greater splanchnic; also the greater splanchnic arising from the fourth thoracic ganglion.

Fig. 8. The more common appearance of the thoracic and lumbar ganglia with their splanchnic branches; also the aorticorenal from the first and second lumbar.

splanchnic nerves emerge through the same aperture in many patients; however, in others they emerge through a separate aperture in the diaphragm. The greater and lesser splanchnic nerves are then detached from the celiac ganglion. The lesser splanchnic nerve usually has fibers entering the celiac ganglion and smaller fibers entering the aorticorenal ganglion (Fig. 3). In the female, the third lumbar ganglion is mobilized and the trunk immediately beneath it divided. In many instances fibers may be seen extending from the third lumbar to the aorticorenal ganglion or directly to the abdominal aorta. In other patients none may be found. The second lumbar ganglion always has a few fibers leading to the aorticorenal ganglion, the first usually having a fairly sizable trunk or at times several small strands of nerve leading to the aorticorenal ganglion (Fig. 8*b*). The rami of the second lumbar ganglion are then divided; the crux of the diaphragm usually covers a part of the first lumbar ganglion. With the distal end of the lumbar trunk kept under slight tension, the crux of the diaphragm is incised and the first lumbar ganglion readily exposed and its rami divided. The incision through the crux of the diaphragm is then increased for a distance of several millimeters so that the aperture in the diaphragm is of sufficient size to permit the ganglia to be pulled through it from above. The mobilized cephalad end of the thoracic trunk and the splanchnic nerve are then grasped with forceps and by gentle traction the subdiaphragmatic portion of the greater and lesser splanchnic nerves, as well as the lumbar trunk, can readily be brought through the diaphragmatic aperture. In this manner the entire system is kept in continuity and there can be no question as to the completeness of the procedure.

Photographs are taken of the specimen so that they may be used for future reference. If, for instance, unusual areas of excessive perspiration develop in a supposedly denervated

area, one can refer to the photograph and determine whether or not the ganglia involved were actually removed. In this manner one can determine, also, at a later date how much regeneration actually takes place in these individuals.

That the operation in competent hands is not associated with great danger is indicated by the fact that one postoperative death has occurred in 250 patients with essential hypertension. This patient died from a coronary thrombosis on the second day following the second stage operation. Superficial wound infections were encountered in 4 cases which were readily controlled by immediate drainage and removal of the black silk sutures. In none of these cases of infection has the thoracic cavity been involved. In several cases slight pleural effusion has developed and in only 3 instances was aspiration thought necessary; in the remaining cases the effusion subsided within a few days without aspiration. Unfortunately, severe postoperative discomfort which was directly due to mechanical intercostal neuralgia occurred in a considerable number of these patients and lasted from several days to several weeks.

SUMMARY

A technique for extensive thoracolumbar sympathectomy is described which allows adequate exposure for removal of the sympathetic system from the fourth thoracic to the third lumbar ganglia, inclusive.

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# EDITORIALS

SURGERY
Gynecology and Obstetrics

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JUNE, 1947

## THE IMPORTANCE OF BLOOD IN PREOPERATIVE AND POSTOPERATIVE TREATMENT

IN order to carry on the important functions of the blood and to meet emergencies, such as sudden loss of blood, trauma, and major operations, an adequate volume of circulating blood must be maintained and enough hemoglobin must be maintained in the erythrocytes to supply oxygen to the tissues. The effects of sudden hemorrhages, such as occur in peptic ulcers, placenta previa, ruptured ectopic pregnancies, ruptured uteri, and pulmonary tuberculosis, may be offset by transfusions of blood. The use of transfusions of blood before operation to minimize or to prevent shock in such cases and to prepare patients who have jaundice or hemorrhagic diseases is generally accepted. In the obstetrical emergencies Rh negative blood should be given when the Rh type has not been determined previously.

It has been found that transfusions of blood will decrease coagulation time. Since transfusion of 100 cubic centimeters of fresh blood usually is enough to produce a hemostatic effect, a preoperative transfusion may make surgical procedures possible in conditions such as jaundice or certain blood dyscrasias in which they would otherwise have been impossible.

Usually a patient with acute or chronic anemia has a marked decrease in blood volume in which case fewer erythrocytes are present to carry oxygen and carbon dioxide, and because of the necessity for increased cardiac output the heart may be strained. A patient who has either acute or chronic anemia may reach the stage of air hunger as a result of the anemia. Anemia may result from slow loss of blood in conditions such as menorrhagia, slowly bleeding ulcer, and rectal disorders (hemorrhoids or neoplasms). If the patient with this type of anemia undergoes operation, trauma or further loss of blood, irrespective of the type of anesthesia, shock, or permanent cerebral damage may ensue because the oxygen supply to the brain is insufficient.

When a patient is anemic, the choice of the anesthetic agent for an operative procedure may be difficult. For example, some operative procedures are best done with the patient under spinal anesthesia. However, if the concentration of hemoglobin is less than 50 per cent, use of this anesthetic procedure is definitely contraindicated.

In the postoperative period, certain additional conditions may be present in which blood transfusions may prove of value. Favorable results of transfusions in treatment of certain infectious diseases have been reported.

The purpose is to add such antibacterial agents as natural antibodies, leucocytes and complement to the blood of the recipient. Immunotransfusions may have even more value.

A patient who is doing well in many respects but does not eat, seems tired and listless and has little strength, frequently responds well to one or more transfusions. The exact reason for this is unknown. The hemopoietic power may have become depleted and not enough blood cells are produced for the patient to carry on a normal convalescence. It is surprising how much the boost offered by a transfusion of blood will help some patients.

In ordering a blood transfusion the physician should not forget that intravenous administration always carries a certain risk. On the other hand, if a blood transfusion is indicated, it should be given. Each 500 cubic centimeters of blood administered raises the concentration of hemoglobin approximately ten per cent and increases the erythrocyte count about 500,000 cells per cubic millimeter. Hence no set amount should be agreed on for all patients. The patient should be given that amount of blood which fulfills the purpose of the transfusion. That amount is not necessarily administered in one transfusion, but may be given in a series of transfusions.

THOMAS H. SELDON

## BLOOD PLASMA

WAR experience has helped to define the usefulness and limitations of blood plasma. The great abundance of plasma available to the armed forces of the United States led to an extensive clinical trial unhampered by supply or economic considerations. The purity and excellence of the plasma and the disposable, sterile, pyrogen free dispensing set provided, allowed administration of large quantities of plasma to individual patients without fear of reaction. An occasional allergic reaction manifested by urticaria was about the only reaction which could be definitely ascribed to plasma. However, physiological disturbances, some of extreme gravity, did result from its improper use.

Of greatest importance is the knowledge gained with the use of plasma and whole blood in wound shock. Early experience demonstrated that those who were resuscitated from shock by the administration of plasma presented a severe secondary anemia in convalescence. Further, those in extreme shock could be resuscitated only with the administration of whole blood. Later laboratory investigations of blood volumes and hematocrit readings demonstrated definitely that lowered blood volume was the important factor in wound shock, and that the lowered blood volume was due to loss of whole blood rather than plasma, with certain few exceptions. Plasma therefore is not the ideal agent in most cases of wound shock, and when so used is frequently a poor substitute for whole blood. When used to restore blood volume it dilutes the remaining red cells. If blood loss has been large, the resulting diluted blood may be so deficient in red cells as to be ineffective as an oxygen carrier in the seriously wounded individual who must have surgical care.

Appreciation of these facts led to the adoption of certain principles of management. The wounded admitted to hospitals in severe shock with no brachial blood pressure were immediately and rapidly given low titer group O blood[1] without waiting for grouping and cross matching of the first liter. Those in less severe shock were administered plasma only while grouping and cross matching were rapidly completed. Forward of hospital units where whole blood was not available, plasma was

[1] Group O blood with anti-A and anti-B agglutins in titer less than 1-64.

given to those in shock in a quantity only sufficient to render them transportable to the nearest hospital unit where whole blood and facilities for surgery were available.

The necessity for whole blood in restoring blood volume was most apparent in those casualties with severe or multiple wounds. If large quantities of plasma were used in resuscitating such individuals they did not tolerate prolonged anesthesia and surgery necessary to the care of their wounds. When whole blood was used in adequate quantities, surgical procedures were well tolerated and frequently extended over a period of many hours. The amount of blood required before and during surgery frequently totalled 3500 to 5000 cubic centimeters and occasionally more was required. In those with minor degrees of shock accompanying wounds which were not extensive and severe, resuscitation and surgical care were occasionally accomplished with, or following, plasma therapy and no blood. However, the margin of safety is certainly greater if every individual in shock from war wounds, or similar injuries receives some whole blood before or during surgery.

While whole blood loss alone accounts for the reduced blood volume in wound shock in the vast majority of cases, there are a few exceptions. In certain abdominal and thoracoabdominal wounds where there is gross contamination or sepsis in the peritoneum or pleura, plasma loss from exudation does occur. These cases most often have whole blood loss from their wounds in addition to the plasma loss. In some cases the whole blood loss is minimal and the plasma loss from exudation is maximal. When the latter situation was discovered at surgery, plasma alone was used in the continued effort to combat shock.

Plasma loss and hemoconcentration were also found to occur in fulminating cases of clostridial myositis or gas gangrene of the wet type. This loss of plasma through the wound or into the involved muscles was best combated with the infusion of large quantities of plasma. These same cases also tended to present a severe anemia and whole blood was necessary as well as plasma.

In cases of burn shock, unless complicated by wounds, the reduced blood volume is due almost entirely to plasma loss. The most common error in the management of burn shock is the failure to administer plasma rapidly enough and in sufficient amount. Best results were secured when the plasma was given as an emergency measure administering it into two veins or with positive pressure, if necessary, to rapidly restore the hematocrit reading to normal. Once a normal reading was obtained, the administration was continued at a sufficient rate to maintain this normal reading. As much as 4000 to 6000 cubic centimeters of plasma were used in the first twenty-four to thirty-six hours in extensive burns. With adequate and energetic therapy burn shock could almost always be controlled. Whole blood was not found necessary in the first thirty-six hours in the management of uncomplicated burns. Secondary anemia developed rapidly thereafter, however, and whole blood then replaced plasma in burn management.

Hemoconcentration and the need for the infusion of large quantities of plasma were found also in crush injuries. The tremendous swelling which developed in the limbs of these unfortunate victims after they were moved from beneath stones and masonry often led to very high hematocrit readings. Their management was often complicated by the development of pigment nephropathy and anuria.

In wartime, plasma was used extensively to correct and prevent hypoproteinemia. Amino acid solutions for intravenous use were never generally available and were not available at

all until late in the war. Patients with severe wounds invariably showed some degree of hypoproteinemia, and in those with abdominal wounds in whom nasogastric suction was continued over a period of days, hypoproteinemia became severe unless plasma was given in proper amounts. It became routine practice to give these patients 500 to 1000 cubic centimeters of plasma daily beside the whole blood needed. Plasma protein determinations by the copper sulfate specific gravity method indicated that 500 to 750 cubic centimeters of plasma daily was sufficient to maintain a satisfactory level in most patients of this sort.

Plasma has a definite and important place in peacetime surgery. It should be available everywhere for emergency management of the shock of severe burns. It should likewise be available for the management of traumatic shock to sustain life until whole blood is available. Its limitations in the management of shock should be well known so that it is not given in large quantities when whole blood is needed. A program to provide properly prepared and packaged plasma at low cost for emergency use throughout the nation would appear to be desirable.

HOWARD E. SNYDER

# THE SURGEON'S LIBRARY

## REVIEWS OF NEW BOOKS

THE recent book by I. S. Smillie[1] encompasses the intricate and difficult task of describing the injuries to the knee joint in a comprehensive monograph. The author presents the subject in a manner which is outstanding in more than one sense. As would be expected a large portion of the book is given over to the discussion of what is commonly called internal derangement of the knee, that is, the lesions of the menisci and the intrinsic ligaments. Another deals with the injuries of the collaterals, a third with those of the extensor apparatus, a fourth with the joint fractures, bones, and injuries to the surrounding soft tissues. The most ingratiating feature is that the author so happily combines precision and clearness in the clinical presentation with conciseness and lucidity in developing for his readers the basic background of mechanogenesis and pathology.

The discussion of the semilunar cartilage injuries is an example. The diagnosis is based on observational points inclusive enough to protect the clinician against disappointment.

With all the weight that is laid upon the comprehensive description of all diagnostic features and their evaluation, one finds there is no tendency to introduce unusual or occasional observations nor to confuse the issue by elevating these to the dignity of diagnostic landmarks, as is so often done in monographs of this kind. Consequently, one will find much which is hardly worth mentioning has been left unsaid.

In each particular section the pertinent facts of mechanogenesis and pathology are stated simply and clearly, and their clinical implications are stipulated with a great deal of plausibility; for instance, the manner of occurrence, the nature and the signs of the different types of meniscal tears. The same can be said of the chapters that deal with the injuries of the collaterals and with the loose intra-articular bodies. There is another redeeming feature about this book, namely, that there is throughout a wholesome tendency of conservatism. While the operative side is discussed comprehensively and one cannot say that any of the current operative methods are omitted, yet it is not given undue prominence. An instance is the emphasis laid upon the development of the quadriceps extensor apparatus as a conservative therapeutic measure.

In fact, the introductory chapter is devoted to the importance of the quadriceps. This is followed in logical sequence by one on secondary traumatic synovitis and hemarthrosis. The surgical anatomy and the specific pathology are dealt with separately along with the individual topics and one will find this presentation clear, concise, and throughly adequate. One chapter devoted to fractures of the tibia and fibula which involve the knee joint is quite attractive, as is the one dealing with the wounds of the knee. Nevertheless, the outstanding chapters, we believe, are those dealing with the internal derangement, those on the collaterals and the free joint bodies, the injuries of the extensor apparatus and, above all, those sections which present prevention and treatment of posttraumatic functional deficiencies by conservative measures.

The wide experience of the author is amply documented by imposing statistics. There is an abundance of roentgenograms covering all illustrative cases, each one bringing out a specific clinical situation: they are numerous and yet do not tire the reader by duplication. Illustrations are excellent, both those in color and those which appear as diagrammatic drawings. In its particular field the book certainly can claim to be a classic.

ARTHUR STEINDLER.

IN a profusely illustrated volume of 350 pages the author of *Demonstration of Physical Signs in Clinical Surgery*[2] describes the more common physical signs in surgical diagnosis. There are 573 illustrations, most of which are photographs, many in color. Although many of the photographs are old they are quite satisfactory. The colored photographs are excellent and admirably illustrate the lesion in question. The text is brief and used chiefly to describe the illustrations and the various signs and tests they illustrate. Credit is given by means of footnotes to those men originally describing a sign or test. The book will be found useful by the student meeting these findings for the first time.

THOMAS C. DOUGLASS.

THE book *The Essentials of Obstetrics and Gynecology*[3] by Scott and Van Wyck is based on the lectures in obstetrics and gynecology given at the University of Toronto. It is divided into two parts, the first covering obstetrics and the second gynecology.

[1] INJURIES OF THE KNEE JOINT. By I. S. Smillie, O.B.E., M.B., F.R.C.S.(Ed.), F.R.F.P.S. Baltimore, Md.: The Williams & Wilkins Co., 1946.

[2] DEMONSTRATION OF PHYSICAL SIGNS IN CLINICAL SURGERY. By Hamilton Bailey, F.R.C.S.(Eng.), F.I.C.S. 10th ed. Baltimore: The Williams & Wilkins Co., 1946.

[3] THE ESSENTIALS OF OBSTETRICS AND GYNECOLOGY. By William Albert Scott, B.A., M.B., F.R.C.S.(Can.), F.R.C.O.G.(Eng.), and H. Brookfield Van Wyck, B.A., M.B., F.R.C.S.(Can.), F.R.C.O.G.(Eng.). Philadelphia: Lea & Febiger, 1946.

Part one, obstetrics, is divided into three sections. Section one covers normal obstetrics. The initial chapter is concerned with a well written and brief discussion of the embryology of the genital system. It also includes a short description of pelvic anatomy which is adequate for the medical student to orient himself. Physiology is divided into a discussion of the changes in the various periods of a woman's life, and is briefly covered in a style that should be easily understood by the student. The physiology of conception is carried along in a sequence that follows logically and reads easily. The discussion of the puerperium is excellent. It is presented concisely with fundamentals and commonly met problems outlined in a practical manner.

Section two deals with abnormal obstetrics. Toxemias, abortion, premature labor, and bleeding are outlined. The diseases complicating pregnancy are briefly discussed. Syphilis could probably have been given more discussion, especially an outline of therapy. Diabetes also deserves more mention, even in an outline type of text. The Rh factor is mentioned and discussed in relation to erythroblastosis fetalis, and even though our knowledge of the relationship and management is meager a more complete discussion might have been warranted.

Section three deals with operative obstetrics. The views expressed are conservative and sound. One illustration shows three types of obstetrical forceps, all of which are designed for the more difficult types of operations. One wonders why the more commonly used instruments are not shown. Two illustrations of instruments used in destructive operations are also shown, but in the short résumé of this operation no mention is made of their specific application.

Part two covers gynecology and is presented in a well planned outline manner. The various gynecological disorders are discussed according to location, starting with the vulva and progressing upward. The discussion of Leucoplakia fails to mention the more than casual relationship to carcinoma; however, later, under the latter heading this relationship is brought out. Carcinoma of the cervix and corpus is briefly but well covered. The use of illustrations in describing these conditions would have been helpful. The authors favor radiation therapy for cervical malignancy and radiation followed by surgery for that in the body of the uterus.

Ovarian tumors are classified in a simple outline form. The treatment of pelvic infections has been given conservative handling. Sulfa drugs are stressed in the treatment of gonorrhea, and penicillin is only mentioned as a hospital treatment for speedy cure. More detail about its use might have been given.

The chapter on endometriosis covers the cardinal points in the disease. Sterility and acquired dysmenorrhea and the more than casual relationship between fibroids, retrodisplacement, and endometriosis might have been stressed more.

A good outline of the causes of vaginal bleeding is presented and diagnostic points in differentiation have been emphasized.

Gynecologic operative procedures are covered in twenty-one pages. Stress is placed on good surgical technique, careful handling of tissues, and hemostasis. A short outline of sensible postoperative care is given. The details of various special operations have been limited throughout, except for a series of illustrations showing the steps in performing a Manchester operation for prolapse. The authors apparently favor this procedure.

This short volume outlining both obstetrics and gynecology should be helpful to students. The authors have adhered to the essentials with the elimination of theory and controversial discussion.

GEORGE B. BRADBURN.

THE book entitled *Uterine Contractility in Pregnancy*[1] is based on some 3,200 individual records of the contractions of 1,200 pregnant women, taken during both pregnancy and labor by means of the Lorand tocograph. The observations have a practical value because they demonstrate the close relationship which exists between the quality of the contractions of pregnancy and that of the same woman during her labor. It was found that each individual possesses her own contraction pattern which persists with relatively little modification throughout all of gestation.

The studies also indicate how a knowledge of the quality of the contractions which appear early in labor can assist the obstetrician in predicting the future quality of the contractions as labor advances and in distinguishing between inertia and disproportion as causes of prolonged labor. Furthermore, the studies made with the utilization of oxytocic drugs emphasize the necessity of using very small and accurately measured doses of such drugs in the treatment of uterine inertia.

The book is the result of diligent studies made over a period of several years. In the list of references are nineteen publications of Murphy on this subject. The text is well written, and easy to read, the type is clear, the charts and tables are instructive, and the paper is of good quality. Anyone interested in obstetrics will find a good deal of information about uterine contractions in both normal and abnormal labor which can be applied in daily practice.

J. P. GREENHILL.

[1]UTERINE CONTRACTILITY IN PREGNANCY. By Douglas P. Murphy, M.D., F.A.C.S. Philadelphia, London, Montreal: J.B. Lippincott Co., 1947.

# CORRESPONDENCE

A NEW TECHNIQUE FOR PULMONARY SEGMENTAL RESECTION; ITS APPLICATION IN THE TREATMENT OF BRONCHIECTASIS—A Correction.

*To the Editor:* In the article entitled "A New Technique for Pulmonary Segmental Resection; Its Application in the Treatment of Bronchiectasis" which appears on pp. 257–268 of the March, 1947, issue of SURGERY, GYNECOLOGY AND OBSTETRICS an error has been made in the arrangement of Figures 8, 9, 10 and 11. Figures 10 and 11 should appear on p. 262 as Figures 8 and 9, and Figures 8 and 9 should appear on p. 263 as Figures 10 and 11.

RICHARD H. OVERHOLT.

# CLINICAL CONGRESS OF AMERICAN COLLEGE OF SURGEONS

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## PRELIMINARY PROGRAM FOR 1947 CLINICAL CONGRESS, THE WALDORF-ASTORIA, NEW YORK, SEPTEMBER 8 TO 12, 1947

PLANS are proceeding for the program of the thirty-third Clinical Congress of the American College of Surgeons which will be held in New York at The Waldorf-Astoria from September 8 to 12. Representatives of the New York hospitals which will participate in the clinical program have been holding meetings to further the scheduling of clinics in as nearly final form as possible. It is expected that a fairly complete schedule of clinics will be compiled in time for publication in the July issue, according to Dr. Howard A. Patterson, Chairman of the local Committee on Arrangements. The program of each hospital will be arranged to cover subjects in general surgery, obstetrics and gynecology, fractures, orthopedic surgery, thoracic surgery, neurosurgery, genitourinary surgery, and ophthalmology and otolaryngology. General and special demonstrations will be held on subjects such as fractures, cancer, maternal morbidity, and end-result studies; newer diagnostic and therapeutic procedures; preoperative and postoperative supportive treatment; anesthesia; and reconditioning. An idea of the scope of the clinical program may be obtained from consulting the August, 1946, issue of SURGERY, GYNECOLOGY AND OBSTETRICS, pages 275 to 288, in which was published the preliminary program prepared last year before the Clinical Congress was transferred from New York to Cleveland.

### PROGRAM IN GENERAL

The usual varied and comprehensive program of meetings at the headquarters hotel is planned. The Presidential Meeting will be held on the evening of September 8 in the Grand Ballroom, with the inaugural ceremony for the incoming officers, the Presidential Address by Dr. Irvin Abell, and the delivery of the second Martin Memorial Lecture. The Convocation, including the presentation of candidates for fellowship and for honorary fellowship, and the delivery of the Fellowship Address, will be held on the evening of September 12. Other official meetings include the Annual Meeting of Fellows on September 11, the Assembly of Initiates on September 12, meetings of the Board of Regents and of the Governors, and meetings of various committees.

Evening sessions will be held on Tuesday, Wednesday, and Thursday, devoted to subjects in the field of general surgery, and also in ophthalmology and otolaryngology, which will be featured in separate meetings.

Afternoon sessions will consist of panel discussions led by recognized authorities in their respective fields, who will be aided by well qualified collaborators. Preliminary plans include the holding on one afternoon of a symposium on fractures and other traumas, and on another afternoon of a symposium on cancer. A number

of panels on the surgical specialties are planned for the final afternoon.

Morning meetings will include separate panel discussions at 11:00 o'clock on Tuesday, Wednesday, and Thursday, for ophthalmologists and otolaryngologists.

### FORUM ON FUNDAMENTAL SURGICAL PROBLEMS

The Forum on Fundamental Surgical Problems will be conducted on Tuesday, Wednesday, Thursday, and Friday mornings. Included will be brief reports of original clinical and experimental observations relating to the broad aspects of surgery and the surgical specialties. No prepared discussions of the reports are planned, but questions and comments will be invited. Dr. Owen H. Wangensteen of Minneapolis, chairman of the committee which is planning the program, is working toward representation of as many as possible of the various university departments of surgery in this presentation of clinical and experimental research work.

The enlistment of the interest of young men who are doing original work, through the Forum, is one of the most beneficial results of these sessions which are now considered to be an indispensable feature of every Clinical Congress.

### HOSPITAL STANDARDIZATION CONFERENCE

The first formal session of the Clinical Congress will be the opening meeting of the twenty-sixth Hospital Standardization Conference. Dr. Irvin Abell of Louisville, President of the College, will preside. The hospital conferences will continue on Monday afternoon, with sessions following on Tuesday, Wednesday, and Thursday mornings, afternoons, and evenings.

Hospital administrators, members of governing boards, heads of the various hospital departments and their personnel, nursing groups, and many other persons directly or indirectly concerned about hospital progress will be interested in the discussion of current hospital problems. National organizations representing various groups of hospital personnel will co-operate and participate in the meetings, which will include formal sessions, panel discussions, round table conferences, and open forums.

### ADVANCE REGISTRATION

The hospitals and medical schools of New York afford accommodations for a large number of visiting surgeons. However, in order to insure against overcrowding, attendance at the Congress will be limited to the number that can be comfortably accommodated at the meetings and also by accommodations in the hotels. It is therefore expected that surgeons who wish to attend the Congress will register in advance.

The members of the Board of Regents regret that conditions beyond their control will not permit unpaid registration at the 1947 Clinical Congress. They voted to restore the registration fee of $5.00 for Fellows and for endorsed Junior Candidates. Non-Fellows attending as invited guests of the College will pay a fee of $10.00. No fee will be required of initiates of the class of 1947.

To each surgeon who registers in advance a formal receipt will be issued. This is to be exchanged for a general admission card upon his registration at headquarters during the Congress. This card is not transferable and must be presented in order to obtain clinic tickets and admission to scientific sessions.

### MEDICAL MOTION PICTURES

The latest available films showing surgical procedures and related subjects will be shown in the medical motion picture exhibits which will be held daily. These are a much appreciated feature of the Clinical Congress.

Both sound and silent, standard and color films will be shown, all of which have been approved by the Committee on Medical Motion Pictures.

### TECHNICAL AND SCIENTIFIC EXHIBITION

The technical exhibit, together with the registration and clinic ticket bureaus, will be located in the Basildon Room, Jade Room, and Astor Gallery, all on the third floor of the hotel. Leading manufacturers of surgical instruments, x-ray apparatus, sterilizers, operating room lights, ligatures, dressings, hospital apparatus and supplies of all kinds, and pharmaceuticals, and publishers of medical books will be represented in the exhibition. The technical exhibits will demonstrate many of the newer features learned from our experience in the war.

### HOTEL RESERVATIONS

Although the prospect is that the hotel situation in New York will be more favorable than it would have been last year, nevertheless there is still a critical shortage of hotel rooms and early reservations are most desirable. In making these, communications should be addressed to the New York Convention Bureau, through which all reservations for the Clinical Congress are to clear. No correspondence should be sent directly to the hotels. A letter has been sent to Fellows in which the procedure is outlined; with this letter was enclosed a form to be used in making

reservations. First, second, third, fourth, and fifth choices of hotels may be designated. The following hotels are recommended by the Committee:

| | Minimum rates with Bath | |
|---|---|---|
| | Single | Double |
| Allerton House, 143 East 39th Street | $2.75 | $ |
| Allerton House for Women, 130 East 57th Street | 3.00 | |
| Ambassador, Park Avenue and 51st Street | 6.00 | |
| Astor, Broadway and 44th Street | 3.50 | 4.00 |
| Barbizon (Women), Lexington Avenue and 63rd Street | 3.50 | |
| Barclay, 111 East 48th Street | 6.00 | 8.00 |
| Belmont Plaza, Lexington Avenue and 49th Street | 4.00 | 6.00 |
| Beverly, Lexington Avenue and 50th Street | 5.00 | |
| Biltmore, Madison Avenue and 43rd Street | 5.50 | 7.50 |
| Bristol, 129 West 48th Street | 2.50 | 3.50 |
| Capitol, 51st Street and 8th Avenue | 3.00 | 4.50 |
| Carlyle, Madison Avenue at 76th Street | 6.00 | |
| Chesterfield, 130 West 49th Street | 2.50 | 4.00 |
| Commodore, Lexington Avenue and 42nd Street | 3.50 | 5.50 |
| Concourse Plaza, Grand Concourse and 161st Street | 3.50 | 5.50 |
| Cornish Arms, 311 West 23rd Street | 2.25 | 4.00 |
| Delmonico, 502 Park Avenue | 6.00 | 8.00 |
| Essex House, 160 Central Park South | 6.00 | 8.00 |
| Fifth Avenue Hotel, 24 Fifth Avenue (9th Street) | 4.00 | 6.00 |
| Governor Clinton, 31st Street and 7th Avenue | $3.30 | $4.40 |
| Henry Hudson, 353 West 57th Street | 2.50 | 3.50 |
| Kenmore Hall, 145 East 23rd Street | 2.00 | 3.50 |
| Lexington, 48th Street and Lexington Avenue | 4.00 | 6.00 |
| Luxor Baths Hotel, 121 West 46th Street | 2.25 | |
| McAlpin, Broadway and 34th Street | 3.30 | 4.95 |
| Martinique, Broadway at 32nd Street | 2.75 | 3.85 |
| Midston House, 22 East 38th Street | 3.50 | 4.00 |
| New Weston, Madison Avenue and 50th Street | 4.00 | 7.00 |
| New Yorker, 34th Street and 8th Avenue | 3.85 | 5.50 |
| Paramount, 46th Street, West of Broadway | 3.00 | 5.00 |
| Park Central, 7th Avenue and 55th Street | 4.00 | 6.00 |
| Parkside, 18 Gramercy Park South | 2.75 | |
| Pennsylvania, 7th Avenue and 33rd Street | 3.85 | 5.50 |
| Piccadilly, 227 West 45th Street | 3.00 | 5.00 |
| Plymouth, 143 West 49th Street | 2.50 | 3.50 |
| President, 234 West 48th Street | 2.50 | 4.00 |
| Prince George, 14 East 28th Street | 2.50 | 4.00 |
| Roosevelt, Madison Avenue and 45th Street | 4.50 | 6.50 |
| Shelton, 49th Street and Lexington Avenue | 3.50 | 5.00 |
| Taft, 7th Avenue and 50th Street | 3.00 | 5.00 |
| Times Square, 43rd Street and 8th Avenue | 2.25 | 4.00 |
| Tudor, 304 East 42nd Street | 2.50 | |
| Victoria, 7th Avenue and 51st Street | 3.00 | 4.50 |
| Waldorf-Astoria, 50th Street and Park Avenue | 7.00 | |
| Warwick, 54th Street at Sixth Avenue | 5.00 | |
| Wellington, 7th Avenue and 55th Street | 3.00 | 4.50 |
| Woodstock, 127 West 43rd Street | 3.00 | 5.00 |

# CLINICAL CONGRESS PROGRAM IN BRIEF

*Monday*

9:30 General Assembly for Surgeons and Hospital Representatives, Grand Ballroom
1:30–3:00 Panel Discussion, Wedgwood Room
2:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
2:00 Hospital Conference, Sert Room
2:00 Surgical Film Exhibition (General), Grand Ballroom
3:30–5:00 Panel Discussion, Wedgwood Room
8:15 Presidential Meeting, Grand Ballroom

*Tuesday*

8:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
9:00–12:30 Forum on Fundamental Surgical Problems, Grand Ballroom
9:30 Hospital Conference, Sert Room
9:30 Surgical Film Exhibition (Eye, Ear, Nose and Throat), Jensen Suite
10:00 Surgical Film Exhibition (General), Wedgwood Room
11:00 Panel Discussions
Ophthalmology—Otorhinolaryngology
1:30–3:00 Panel Discussion, Grand Ballroom
2:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals.
2:00 Hospital Conference, Sert Room
2:00 Symposium on Fractures and Other Traumas
2:00 Surgical Film Exhibition (General), Wedgwood Room
3:30–5:00 Panel Discussion, Grand Ballroom
7:00 Surgical Film Exhibition (Eye, Ear, Nose and Throat), Wedgwood Room
7:30 Hospital Conference—Trustees, Sert Room
8:00 Scientific Session, General Surgery, Grand Ballroom
8:00 Scientific Session, Ophthalmology, Jensen Suite
8:00 Scientific Session, Otorhinolaryngology, Le Perroquet Suite

*Wednesday*

8:00 Meeting of Cancer Committee, Carpenter Foyer and Dining Room
8:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
9:00–12:30 Forum on Fundamental Surgical Problems, Grand Ballroom
9:30 Hospital Conference, Sert Room
9:30 Surgical Film Exhibition (Eye, Ear, Nose and Throat)
10:00 Surgical Film Exhibition (General)

*State and Provincial Committees:*

9:30 Executive Committees
10:15 Credentials Committees and Committees on Applicants
} Wedgwood Room
11:00 Judiciary Committees
11:00 Panel Discussions
Ophthalmology
Otorhinolaryngology
12:00 Meeting of Board of Governors, Jensen Suite
1:30–3:00 Panel Discussion, Grand Ballroom
2:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
2:00 Symposium on Cancer, Wedgwood Room
2:00 Surgical Film Exhibition (General)
2:00 Hospital Conference, Sert Room
3:30–5:00 Panel Discussion, Grand Ballroom
6:00 Vandyck Reunion Dinner, Le Perroquet Suite
7:00 Surgical Film Exhibition (Eye, Ear, Nose and Throat) Wedgwood Room
7:30 Hospital Conference, Sert Room
8:00 Scientific Session, General Surgery, Grand Ballroom
8:00 Scientific Session (Eye, Ear, Nose and Throat), Empire Room

*Thursday*

8:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
9:00–12:30 Forum on Fundamental Surgical Problems, Grand Ballroom
9:30 Hospital Conference, Sert Room
9:30 Surgical Film Exhibition (Eye, Ear, Nose and Throat)
10:00 Surgical Film Exhibition (General), Wedgwood Room
11:00 Panel Discussions
Ophthalmology
Otorhinolaryngology
1:30 Adjourned Meeting, Governors, Grand Ballroom
1:45 Annual Meeting, Fellows, Grand Ballroom
2:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
2:00 Hospital Conference, Sert Room
3:00 Panel Discussion—Graduate Training in Surgery, Jensen Suite
3:30–5:00 Panel Discussion, Grand Ballroom
3:30 Surgical Film Exhibition (General), Wedgwood Room
3:30 National and Regional Fracture Committee, Le Perroquet Suite
4:00 Committee on the Library, Room 4-J
7:00 Surgical Film Exhibition (Eye, Ear, Nose and Throat), Wedgwood Room
8:00 Scientific Session, General Surgery, Grand Ballroom
8:00 Scientific Session, Ophthalmology, Wedgwood Room
8:00 Scientific Session, Otorhinolaryngology, Sert Room

*Friday*

8:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
9:00–12:30 Forum on Fundamental Surgical Problems, Grand Ballroom
9:30 Surgical Film Exhibition (Eye, Ear, Nose and Throat)
10:00 Surgical Film Exhibition (General), Wedgwood Room
1:30 Assembly of Initiates, Grand Ballroom
1:30 Panel Discussion, General Surgery
2:00 Clinics, Demonstrations and Clinical Group Conferences, selected local hospitals
2:00–4:00 Panel Discussions
Obstetrics, Sert Room
Plastic Surgery, 4-U Blue Room
Neurological Surgery, Assembly Room M-N
Thoracic Surgery, Jensen Suite
Urology, Le Perroquet Suite
Orthopedic Surgery, Carpenter Foyer and Dining Room
2:00 Surgical Film Exhibition (General), Wedgwood Room
3:30 Panel Discussion, General Surgery
8:15 Convocation, Grand Ballroom

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